Effect of Two Training Recovery Intervals on Performance and Cardiovascular Fitness Parameters in High School Track Sprinters

by

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EFFECT OF TWO TRAINING RECOVERY INTERVALS ON PERFORMANCE AND CARDIOVASCULAR FITNESS PARAMETERS IN HIGH SCHOOL TRACK SPRINTERS

By

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One of the problems which high school coaches encounter in training runners for competition concerns the amount of rest each runner should be allowed between bouts of running. Interval training techniques generally provide a period of recovery based on time or a distance traveled by walking or jogging as recovery between exercise bouts. Recovery differs with the distance and intensity of the run accomplished; however, recovery is usually the same length in time or distance for all runners even though each is in a different state of fitness. This study was undertaken in an attempt to find a reliable scientific method of recovery of the heart rate as a means of determining the proper interval of rest between bouts of intense, short distance speed running.

Twenty-one high school students training as sprinters on the track team were used as experimental subjects. These subjects were randomly placed into one of two groups who received identical training regimes for six weeks, with one exception. Subjects in group one recovered to a heart rate of 150 beats/minute between running bouts, while the subjects in group two recovered to 120 beats/minute. Eleven members of the school baseball team were randomly selected as a control group. These subjects represented high school athletes similar to the experimental groups in age and other physical parameters, but differing in training habits.

The thirty-two subjects were given three physical tests to determine speed and cardiovascular fitness. The Harvard Step Test and an Oxygen Uptake Test were given as a measure of cardiovascular fitness, and a Sprint Performance Test was developed by the researcher to measure speed as determined by times on selected sprints.

Significant improvement in speed was found for group one and for group two, but no improvement was found for the control group. Group one showed a slightly greater but nonsignificant increase in speed over group two, indicating that for these two groups, a recovery heart rate of 150 beats/minute was sufficient rest, insofar as improvement in speed is concerned, between repetitions of running. Economy of time in practice follows as the result of using a high recovery heart rate when training.

All three groups showed a significant improvement on the Harvard Step Test after three weeks of training, indicating that the training regime of each group, though different, was intense enough to cause faster recovery of the heart rate. The experimental groups continued to improve during the final three weeks of training, but the control group showed a decrease to a point of no significance from pre- to posttest. The training regime of the experimental groups was sufficient to show improved fitness throughout the study.

On the maximum Oxygen Uptake Test, all groups showed statistically significant increase indicating that the intensity of work done

was sufficient to cause better oxygen consumption and therefore, improved cardiovascular fitness. The experimental groups showed a greater although nonsignificant increase in oxygen consumption than did the control group.

On the basis of these findings, it is felt that the use of the recovery heart rate to determine the interval of rest required by high school sprinters between bouts of running represents a reliable method of controlling this factor of interval training. Furthermore, an economy of time is gained when using a heart rate of 150 beats/minute as against 120 beats/minute. Finally, a recovery of 150 beats/minute is sufficient for the high school sprinter between bouts of full speed running, if the distance of the run is kept short--from 50 to 120 yards.

CHAPTER I

INTRODUCTION

One of the problems which high school track coaches have in training track performers is determining how much rest the runner needs between intervals of running, particularly since the individual is usually practicing with a number of other runners simultaneously. Suggested training techniques generally indicate a distance to be run followed by a distance of jogging or walking, or a specified period of time as a recovery between running bouts.

Need for the Study

Since each individual is endowed with different physical potential and since each is in a different state of physical fitness, the period of recovery may be too short for some and too long for others. Assigning a recovery period of distances of jogging or specified time intervals for each performer may become somewhat tedious as distances and times would need to become altered as the runners begin to improve in cardiovascular fitness. An easier, reliable scientific method of determining the optimum recovery period for the individual between running bouts which can be used by the coach on the field is needed. This study was undertaken in an attempt to find such a method for use by the high school track coach.

In this study, prospective members of the varsity track team of the P. K. Yonge Laboratory School, University of Florida, Gainesville, served as the experimental subjects. These students were divided into two groups receiving the same training regime in regard to the distances run, intensity of running, the amount of running accomplished each day, and the recovery position during intervals of rest. The variable studied was the recovery of the heart rate. Group one (G1) rested in the standing position and recovered to a heart rate of approximately 150 beats/minute and group two (G2) rested and recovered to approximately 120 beats/minute between running bouts. A control group (GC) was selected from members of the varsity baseball team of the same school. These subjects represented high school athletes similar to the experimental groups in age and other physical parameters, but differing in training habits.

Interval Training

The method most used in training track performers is interval training. There are five major factors to consider in interval training. These factors are: (1) distance or the duration to be run, (2) intensity or pace to be run, (3) number of repetitions to be accomplished, (4) recovery time between efforts, and (5) actions and postural position of the athlete while in the recovery phase. By varying any one of these five factors, the nature of the physical workout can be changed considerably. For instance, when keeping the other four factors constant, a runner who runs at 90 percent of his maximum speed works much harder than the runner who runs at 50 percent of maximum.

Bloomfield discusses five main types of interval training which have been used for the past twenty years (10). Of the five types, four of them have each runner recovering for a specified period of time, from five seconds to three minutes, varying with the other four factors of interval training. It would seem that a basic weakness is inherent in the principle of recovering all runners for the same period of time, when it is obvious that each individual is in a different state of physical fitness.

Bloomfield also discussed the Gerschler-Reindell method, which utilizes the return of the heart rate to a certain number of beats per minute as the recovery time between repetitions of running (10).

Purpose of the Study

It was the purpose of this study to investigate the effectiveness of using the recovery of the heart rate as a means of determining the interval of rest which a high school sprinter requires between repetitions of running when training for competition. This study differs from the Gerschler-Reindell method primarily in the intensity of the run and in the recovery position of the athlete between running bouts.

Definitions

There are numerous track and physiological terms used in this study. An understanding of the meaning of the following terms is essential in reviewing this study.

Cardiovascular fitness refers to the oxygen transporting capacity of the cardiorespiratory system (29). The state of the cardiovascular fitness of an individual defined thusly, can be measured by maximal oxygen uptake. The terms fitness and physical fitness are used interchangeably with cardiovascular fitness.

Heart rate is the number of times the heart beats per minute.

Recovery implies a return to a relatively normal resting state after exercise. Recovery heart rate implies a return to a designated number of heart beats per minute following exercise.

Interval training is a principle which implies physical work of a given intensity, interspaced with periods of rest between periods of work.

Training is physical work engaged in for the purpose of increasing efficiency in running and racing. The term conditioning is used as well as training in this study.

A workout includes the physical work accomplished during one training session.

A workout is preceded by a warmup, preliminary exercises used as mental and physical preparation for intense physical work. Each workout is followed by a warmdown, exercise decreasing in intensity designed to aid the physiological functions of the body to return to pre-exercise levels.

Jogging is running at a slow speed, usually two to three minutes for a 440 yard run.

Sprinting is running at maximum speed.

Striding is running at any speed between jogging and sprinting.

Speed is the rate at which successive movements can be performed. In this study speed is measured by timing the subject in maximum sprinting efforts of 110, 200, and 220 yards.

Stress is any condition which puts an unusual burden on the subject.

Endurance is the ability to withstand stress as a result of prolonged work leading to body fatigue.

Metabolism refers to all the chemical reactions which occur in the cells of the body, and in track training metabolism refers to the chemical processes by which food is converted into the energy needed for intense exercise (46).

Aerobic means "with oxygen" and aerobic metabolism occurs when there is an adequate supply of oxygen available in the muscles to convert food into energy. Aerobic endurance is the ability to withstand fatigue over a prolonged period of time when there is an adequate supply of oxygen available (46).

Anaerobic means "without oxygen" and anaerobic metabolism occurs in the muscles when there is an inadequate supply of oxygen transported by the blood to the muscles. Anaerobic endurance is the ability to withstand fatigue when there is an inadequate supply of oxygen. Anaerobic endurance is also referred to as speed endurance (46).

Lactic acid is formed as an end product to anaerobic metabolism and is detrimental to muscular efficiency, causing pain and eventual cessation of physical activity.

Oxygen debt is the difference between the amount of oxygen required while exercising and the oxygen intake during exercise.

Alacticid debt is a condition in which some oxygen debt occurs but no lactic acid is formed in the muscles.

Hollow sprints is a form of interval training in which the runner alternates full speed running with jogging for specified distances (Appendix A).

Buildups, also known as acceleration sprinting, is the gradual increasing of speed from jogging to striding to full speed sprinting, followed by a recovery distance of walking (46) (Appendix A).

Constant Factors of the Training Regime

To improve speed, the skill must be practiced at least as fast as used in competition. Since the improvement of speed is of primary importance to track athletes, the subjects were asked to run at full speed during the working portions of the running bouts.

The number of repetitions accomplished daily were progressively increased from the beginning of the training program through the six weeks of training to allow the subjects to adjust to the stresses of training.

The distances which the subjects traveled in each full speed portion of the practice sessions were kept short, usually between 55 and 110 yards. Short distances were used in order to keep a low level of blood lactate in the muscles (18). Accumulation of lactic acid in the muscles limits muscular activity by causing pain and the cessation of muscular contractions (46).

In ordinary exercise the energy needed for muscular contraction can be supplied aerobically; that is, adequate oxygen is supplied to the muscles by the cardiorespiratory system to satisfy the metabolic demands of the body during exercise. During intense physical activity, such as full speed sprints, energy is supplied through anaerobic processes, i.e., processes occurring without oxygen. In such heavy exercise, the supply of oxygen is insufficient to meet body demands, and the individual is said to contract an oxygen debt. This oxygen debt must be repaid by consumption of more oxygen per minute than in the resting state during the recovery period after running. Furthermore, lactic acid accumulates in the muscles as an end product of metabolism in intense running. The increase in lactic acid is in proportion to the oxygen debt contracted.

Oxidation of lactate occurs as the oxygen debt is being repaid. In such intense running, where anaerobic processes prevail, duration of exercise is limited to about thirty seconds, and the recovery period may be quite long (up to ninety minutes), depending upon the amount of lactic acid which has accumulated in the muscles (18).

A recovery period of such duration is impractical in track practice. Therefore, full speed sprints, involving anaerobic processes, were kept short, minimizing lactic acid buildups and thereby providing for faster recovery.

After running each required distance, the experimental subjects walked to a designated area and recovered in a relaxed, standing position while waiting for the next bout of running. This differed from the study by Gerschler (25) in which the athletes recovered while lying down. Although it has been shown that recovery of the heart rate is faster when lying (21), the subjects in this study recovered by walking and remaining in the standing position to prevent undue pooling of the blood (18, 21).

Tests Used in the Study

Three tests were given to all subjects in this study. An Oxygen Uptake Test ($\dot{V}O_2$) was given as a pre- and posttreatment test of cardiovascular fitness. The Harvard Step Test (HST) was given as a pre-, mid-, and posttreatment test of cardiovascular fitness. A Sprint Performance Test (SPT) was developed and given as a pre-, mid-, and posttreatment test of speed ability as measured by improved times on the test.

Parameters Examined

Changes in cardiovascular fitness as measured by scores obtained in the Harvard Step Test and the Oxygen Uptake Test, and changes in running speed as measured by times on the Sprint Performance Test were compared between group one and group two, group one and control, group two and control, and group one plus group two and control.

The relationship between the Harvard Step Test and the Oxygen Uptake Test, between the Harvard Step Test and the Sprint Performance Test, and between the Sprint Performance Test and the Oxygen Uptake Test were found.

The maximum heart rate attained by each subject performing the Sprint Performance Test was found and used as the cutoff point in the Oxygen Uptake Test. The change of the maximum heart rate as the result of training was also examined.

Assumptions and Summary

It was assumed that the most efficient working threshold for high school runners occurred between a heart rate of 150 beats/minute and the maximum heart rate. Work done at less than 150 beats/minute was felt to be of little value to the sprinter in improving his speed and in being able to hold his times in subsequent sprints with limited recovery. Therefore, in practicing for competition by using short distance speed work, a recovery of 150 beats/minute was felt to provide for sufficient rest between bouts of running.

Certain principles of track training were practiced throughout the study. The training was individualized to meet the specific needs of each subject as to the recovery heart rate of each subject. Early training sessions were relatively light to provide for gradual adaptation to the physiological stresses of training. The workload became progressively more difficult as the training sessions continued through the six weeks. Daily workouts were varied to prevent boredom.

Significance of the Study

This study was undertaken in an attempt to determine the effectiveness of using the recovery of the heart rate as a means of determining the interval of rest which a high school sprinter requires between repetitions of running when training for competition. Should significant differences occur among the three groups in speed as measured by times on the Sprint Performance Test, and cardiovascular fitness as measured by the Harvard Step Test and the Oxygen Uptake Test, then the track coach would have an easy, reliable scientific method of determining recovery periods for individuals participating in high school track practices.

CHAPTER II

REVIEW OF THE LITERATURE

Development of Speed by Running

Although speed is largely a natural or inherited characteristic (10, 39), there are training techniques which the coach can employ to develop speed in trackmen. In attempting to develop speed by running, maximum effort is suggested by many researchers. Mollet maintains that to improve speed, the organism must adapt and react to high frequency excitation. The runner must exercise at his greatest speed (39). deVries agrees stating that if the development of speed is desired, then the skill must be practiced at rates as fast as speed used in competition (18). Wilt suggests that the development of speed involves running sprints of short distances at maximum speed (46).

Distance of Run and Lactic Acid

Other researchers point out the importance of keeping the exercise distance short when running sprints at maximum speed (19). Mollet has pointed out that exercise distance must be short because the strength it requires cannot be maintained for an extended period (39). deVries notes that distances must be kept short if an acceptable level of blood lactate is to be maintained (18). Almond maintains that during severe exercise, the work time will be limited by the accumulation of anaerobic metabolites, notably lactate acid, and that high concentration of lactate acid makes further exercise intolerable (3). Margaria, Edwards, and Dill have established that for the first two and one-half liters of oxygen debt contracted, no increase in lactate can be shown, a condition known as alactacid debt (34). With an increase in oxygen debt beyond that level, however, there exists a direct relationship of oxygen debt to lactate (34). For a distance of 100 meters, run at maximum effort, an oxygen debt of eight to ten liters is accrued. For a distance of 200 meters, this oxygen debt is increased from eighteen to nineteen liters (46), which approaches the limit of oxygen debt which man can endure for continuous work (18). In a study undertaken by Berben, in which the subjects ran four, 50-yard dashes per 440-yard lap at close to maximum speed, high blood lactic acid was not caused by these short intense sprints (9).

Exercise Heart Rate

To improve exercise tolerance of the heart, the intensity of training must be above a certain heart rate threshold value (39), that is, the work in which a person engages must be severe enough to drive the heart rate above a certain number of beats per minute. Sharkey suggests that exercise intensities should cause the heart to work between 150 beats/minute and the maximum heart rate (41). Karvonen reports that a heart rate of 150 beats/minute or above is necessary for beneficial lowering of the exercise heart rate (31, 32). Karvonen, Kentala, and Mustala discuss a training threshold of 150 heart beats/minute as necessary to increase tolerance for exercise (33). Various formulas have been devised to find the threshold value for the individual runner using the maximum heart rate as the top parameter and the resting pulse as the lower parameter in arriving at the threshold value (24, 26, 38).

The Recovery of the Heart Rate in Training

One can work longer and accomplish more work if he is allowed a period of rest between work sessions (16). Interval training is based on this principle (10, 39).

The use of recovery of the heart rate as an indication of when to return to exercise is discussed in the literature (11, 14, 20, 22, 24, 25). Bork reports that recuperation and rest is just as important as training (11). Fauconnier maintains that the beginning of the recuperation phase is the principle element in interval training, rather than the effort expended itself (24). Down elaborates on the need for a scientific means for computing the recovery period required by the individual, and he suggests that the heart rate can act as a reliable indicator for determining the correct interval of rest needed between running bouts (20). He feels that if the heart rate can differentiate among individuals with sufficient precision, then the coach will have at his disposal an easy method for determining recovery intervals (20). Bowers discusses the relationship between oxygen consumption and heart rate, and points out that meaningful observations in regard to cardiovascular fitness can be made by the coach on the field with no equipment available other than the stop watch, by ascertaining the runners' heart rate when engaged in intense workouts (12). Durnin states that the precise relationship between heart rate before and during exercise, as well as with differing levels of fitness, are still sufficiently unclear as to suggest that more research is needed in these areas (22).

Different recovery rates are found in the literature. Many writers suggest heart rate recovery of 120 to 130 beats/minute (20, 26, 38, 45, 46). Others use a formula for arriving at a recovery rate for each individual (24, 38). For example: compute one-third the difference between the resting rate and the exertion rate and then subtract this difference from the exertion rate, i.e., exertion rate of one hundred seventy minus resting rate of fifty-five divided by three equals thirty-eight. One hundred seventy minus thirty-eight equals one hundred thirty-two. This figure, one hundred thirty-two, represents the figure where the heart rate tends to stabilize and descend slower for this individual, and thereby becomes the rate at which exercise may resume (24).

Maximum Heart Rate and Oxygen Uptake Test

It is important that the true maximum heart rate be found when this figure is used as the cutoff point in the Oxygen Uptake Test. Nagle and Bedecki found 180 beats/minute to be a valid cutoff point when working with college men aged eighteen to thirty-six (40). However, Alderman states that the average maximum heart rate in college students is undoubtedly higher than 180 beats/minute (2). Wyndham found the average maximum heart rate among forty army recruits to be 196 beats/minute (47). Åstrand reports that there is a gradual decline in maximum heart rate from 210 beats/minute at age ten to 160 beats/minute in the sixties (4). This is substantiated by Metz and Alexander who found the mean maximum heart rate for twelve and thirteen year old boys to be 199 beats/minute and for the fourteen and fifteen year old boys to be 196 beats/minute (36, 37).

Hermansen found that the maximum heart rate is related to fitness in that fit subjects have lower maximum heart rates than unfit subjects (28). Bower states that conditioned athletes are characterized by having low resting heart rates and low maximum heart rates (12).

Obtaining the maximum heart rate while the athlete is actually performing is difficult; however, McArdle reports that an estimate of maximum heart rate accurate to 2.7 percent may be attained within ten seconds after exercise if the maximum heart rate reached is at least 180 beats/minute (35). Christensen states that when working conditions are such that maximum heart rate cannot be taken while a person is working, post exercise values, taken within five seconds are reliable indicators of the actual work situation (16).

The Oxygen Uptake Test

That Oxygen Uptake Test is a valid measure of physical fitness is well supported in the literature (4, 6, 7, 8, 15, 23, 42, 44, 47). Oxygen uptake is accepted by exercise physiologists as the best measure of cardiovascular fitness (4, 23). Åstrand and Rhyming report that a person's aerobic capacity/kilogram of body weight/minute gives a good test of cardiovascular fitness (6). Research has further established that there is a linear relationship between heart rate and oxygen uptake almost up to the maximum heart rate (1, 4, 6, 8).

In a study of sixty young teenage boys, Metz and Alexander found the mean maximal oxygen intake obtained for the twelve to thirteen year old group to be 50.88 ml/kg/min and the mean for the fourteen to fifteen year old group to be 53.26 ml/kg/min (36, 37). Åstrand found an average of 59.2 ml/kg/min for seventeen year old, 61.6 ml/kg/min for eighteen year old, and 61.3 for nineteen year old well trained male subjects (5). Hermansen and Anderson compared young Norwegian male and female athletes with sedentary young people between the ages of twenty-one and twenty-eight years of age. The male athletes averaged 71 ml/kg/min as compared to 44 ml/kg/min for sedentary males. The female athletes averages 55 ml/kg/min as compared to 38 ml/kg/min for the sedentary group (28).

The Harvard Step Test

The Harvard Step Test is another commonly used test of physical fitness (13, 17, 27, 30, 36, 37), particularly as it is easy to use on the field as opposed to tests given in the laboratory. The Harvard Step Test utilizes the recovery of the heart rate solely as the indicator of cardiovascular fitness (13).

The literature contains many more studies concerning the maximum heart rate, recovery heart rate, and other recovery periods used in training for track and other physical activities. As there are differences of methods of using the heart rate, differences in suggested heart rate threshold values for tolerance of exercise in training, and differences in approaches to using the heart rate in obtaining maximum oxygen uptake, it seems evident that further research in these areas of training and the heart rate is needed.

CHAPTER III

METHODS

Subjects

The subjects used in this study were students from the varsity baseball and track teams of the P. K. Yonge Laboratory School of the College of Education at the University of Florida in Gainesville, Florida.

At the beginning of the study there were 36 subjects. Twelve baseball players were selected from a table of random numbers to serve as a control group. Twenty-four members of the track team who were performers in the sprints and/or the long jump, high jump, and pole vault made up the two experimental groups. The names of these boys were put in alphabetical order and numbered one through twenty-four. They were then assigned to one of the two experimental groups by use of a table of random numbers. A toss of the coin determined which of these groups was to be experimental group one and experimental group two.

During the seven weeks of treatment and pre- and posttesting, four subjects were lost to the study. One baseball player sustained a knee injury and quit the baseball team after four weeks of practice leaving eleven subjects in the control group. One member of group two sustained an injured ankle and was unable to continue the experiment, leaving eleven subjects in group two. One member of group one was removed from the study because he consistently failed to follow the proper training regime. Another member of this group sustained a minor muscle injury and was unable to continue, leaving a total of ten members who completed the study in group two. There were, therefore, 32 subjects who completed the study.

The subjects ranged in age from fourteen years eight months through eighteen years three months old. They were enrolled in school grades nine through twelve at P. K. Yonge (Table 1). The control group had an average age of sixteen years two months. Group one had an average of sixteen years six months, and group two had an average age of sixteen years seven months at the beginning of the study (Table 2).

All subjects, except two, were white. There was one Negro subject in each of the two experimental groups. They were not deliberately placed but rather fell into these groups by the method of randomization.

In accordance with the Florida High School Activities Association and P. K. Yonge school policy, all subjects had passed a physical examination before participation in the program, and the physical examination card for each subject was on file in the Athletic Department Office of the school. Furthermore, parental consent forms were also on file in the office.

Procedures

The pretests were given during the week preceding the beginning of the six week training period. The Harvard Step Test was given first to each of the subjects early in the week. The Sprint Performance Test was given the next day to each subject. The Oxygen Uptake Test was given during the next four days to each of the subjects.

Table 1. Number of Subjects in Each Grade Level of School

Subject	Ninth grade	Tenth grade	Eleventh grade	Twelfth grade	Total
Control	1	5	2	3	11
Group one	1	2	4	3	10
Group two	1	3	4	3	11
Total	3	10	10	9	32

Table 2. Age Distribution and Mean Age of Subjects in the Three Groups

Subjects	No. in 14 yr., 6 mos. 15 yr., 5 mos.	No. in 15 yr., 6 mos. 16 yr., 5 mos.	No. in 16 yr., 6 mos. 17 yr., 5 mos.	No. in 17 yr., 6 mos. 18 yr., 5 mos.	Mean age for group
Control	4	2	3	2	16 yrs., 2 mos.
Group one	2	3	3	2	16 yrs., 6 mos.
Group two	1	4	3	3	16 yrs., 7 mos.
Total	7	9	9	7	16 yrs., 5 mos.

At the end of three weeks of training, the Harvard Step Test and the Sprint Performance Test were given on consecutive days to each of the subjects.

At the completion of the six weeks training program, the tests were again administered in the same order, with the Harvard Step Test and Sprint Performance Test being given to each subject on consecutive days and the Oxygen Uptake Test being given during two days of testing. The control group took the Oxygen Uptake Test on day one and groups one and two were administered the test on the following day.

Three notable exceptions were made. Two boys began training one week later than the majority group of subjects due to illness to one and a previous obligation by the other. The tests for these two were given in the same order and followed the same procedure as with the other subjects but were given a week later. The third exception was made for a subject who missed four consecutive practices during weeks four and five due to illness. He was allowed an additional four days of practice to account for the days missed, and he took the posttest at the same time as the other two exceptional subjects. The pre- and mid-test for this subject were taken at the same time as his experimental group took the tests.

The Harvard Step Test

The Harvard Step Test was given to groups of five subjects simultaneously by the investigator with the assistance of a trained college undergraduate physical education student.

The test was explained to the subjects and they were allowed to practice the test for twenty seconds, at which time they sat down and counted their heart rate by palpating the carotid artery for thirty seconds. At this time unusually high or low heart rates were identified to check for accuracy by the investigator or the assistant during the actual test.

The subjects then performed the five minute Harvard Step Test by stepping up and down on a twenty inch bench at a rate of thirty times per minute. Cadence for the step test was called out by the investigator in the following manner, "up, two, three, four, up, two, three, four," throughout the entire five minutes. At the completion of the test, the subjects sat down on the bench for the recovery period. The heart rates were counted by each subject at one to one and one-half, two to two and one-half, and three to three and one-half minutes after exercise was terminated. These heart rates were then totaled and converted to a raw score as devised by Brouha (13). As indicated previously, subjects who had been identified as having unusual heart rates were immediately checked by the investigator or the assistant. Scores for all three groups in this study are found in Appendix C.

This procedure was followed uniformly during the pre-, mid-, and posttreatment testing.

The Sprint Performance Test

The Sprint Performance Test was developed by the investigator to test the speed of the subjects. The Sprint Performance Test consisted of three sprints to be run at maximum speed. The first sprint was a 110 yard dash, followed by a twelve minute period of recovery by walking around the track at each subject's desired pace. The second sprint was a 200 yard dash, again followed by a twelve minute period of recovery by walking. The final sprint was a 220 yard dash. The times run on each sprint were totaled for a raw score on the Sprint Performance Test.

The distances chosen for the sprints and the time of recovery allowed, simulated the events which a sprinter might run in a dual track meet. The recovery time of twelve minutes represents a minimum amount of time which a sprinter would have to recover in most dual meets. There is an element of conditioning as well as pure sprinting ability contained in the second and third sprints with the short period of recovery allowed. The ability of the athlete to hold his speed through the third event of an interscholastic meet is a very important consideration for the coach in planning and using his trackmen during competition.

The Sprint Performance Test was given to all students on the same day so that the number of daily training sessions, track conditions, and weather conditions were similar. The test was conducted on the grass track at the P. K. Yonge Laboratory School. The track was in good condition for all three testing periods. The wind was negligible and the temperature was in the seventies during each testing period.

Six Minerva 136L stop watches were used for timing the Sprint Performance Test. These watches were checked by Robertson Jewelers of Gainesville, Florida, for accuracy prior to the first testing period, and they were checked against one another prior to subsequent testing periods.

The control group was tested first, followed by the two experimental groups. Three subjects of near equal sprinting ability ran simultaneously. All subjects were instructed to run at maximum speed regardless of the performance of the other two subjects running with them. All subjects were started from a standing position by the assistant using a .22 calibre blank starting pistol. False starts were terminated and immediately restarted. The investigator timed the first and third runner to cross the finish line and a trained student manager timed the second runner to finish. As soon as the third runner crossed the line, a ten second heart rate was taken in the following manner. The investigator said, "heart rate, mark, set, count," and the subjects each counted his own heart rate for ten seconds, at which time the command to "stop" was given by the investigator. The times and heart rate for each subject was immediately recorded by the investigator or a student assistant. The next group of three subjects was then started by the starter two minutes after the first group had started on a signal from the investigator.

On completing the first run, the subjects walked around the track for twelve minutes, at which time they ran the second sprint. The same procedure for timing and obtaining heart rates was used, and the subjects again recovered by walking for twelve minutes before running the third and final sprint.

The times of the three sprints were added for a total score on the Sprint Performance Test. The purpose of taking the heart rate was to ascertain a maximum heart rate for each individual subject, to be used as a cutoff point when taking the Oxygen Uptake Test. The highest of the three heart rates found after sprinting was used as the individual's maximum heart rate.

This procedure was uniformly followed during the pre-, mid-, and posttreatment Sprint Performance Test.

The Oxygen Uptake Test

The Oxygen Uptake Test was given in the Research Laboratory of the College of Physical Education, Health, and Recreation at the University of Florida in Gainesville, Florida. Each subject was first weighed to ascertain his current weight in kilograms. A nose clip was then placed on the subject. During the pretest, the subject was allowed to walk on the treadmill at zero percent grade at a speed of 3.5 miles per hour for thirty seconds to one minute, or until the subject felt comfortable while walking.

The subject then began to take the test. He walked on the treadmill at a speed of 3.5 mph. The elevation of the treadmill was changed each minute, progressing from zero grade to five degrees, ten degrees, and then fifteen degrees. At this point the treadmill was elevated in increments of two degrees grade each minute until the subject's maximum heart rate as identified by the Sprint Performance Test was reached. The subject did not walk with the mouth piece in his mouth during the balance of the test, although he did practice walking with the mouth piece in for approximately fifteen seconds when he was at fifteen degrees elevation on the treadmill. Heart rate was taken at the carotid artery during the last ten seconds of each minute by the investigator.

On the pretest, all subjects reached maximum heart rate on or before the elevation of twenty-seven degrees grade of the treadmill. On the posttest, it was necessary to lower the treadmill for one control subject and two subjects each in groups one and two to zero grade and have them run at seven mph for one minute to elicit a maximum heart rate. After one minute of running, the treadmill was raised back to twenty-three degrees grade, and raised two degrees each minute until maximum heart rate was reached.

When the subject reached his maximum heart rate, he was asked to continue walking for thirty seconds while he exhaled through the mouth piece into a ninety liter saran plastic bag, hereafter referred to as the oxygen bag. The sample of gas collected was then immediately analyzed in a Beckman O_2 Analyzer for percentage of oxygen. The percentage of carbon dioxide produced was analyzed by a Capnograph CO_2 Analyzer. The volume of expired air was measured by a dry spirometer. This figure was multiplied by two to get a one minute sample and one liter was added to account for the gas used in the Beckman O_2 Analyzer and the CO_2 Analyzer. Barometric pressure and room temperature were determined to obtain a correction factor from the line chart for determining factors to reduce saturated gas volume to dry volume at 0° C. and 760 mm hg from Consolazio (17). The uncorrected volume of air was multiplied by the correction factor to get the corrected volume. True oxygen was determined from the percentage of O_2 used and CO_2 produced by use of the line chart for calculating true oxygen from analysis of expired air (17). The corrected volume was multiplied by true oxygen to determine the oxygen uptake in liters. This figure was then divided by the subject's weight in kilograms to determine the ml/kg/min.

Appendix E contains the baseline data used to determine ml/kg/min used by each subject in the pre- and posttest. An example of cards used to determine ml/kg/min for each subject is as follows:

Name Subject 18

O_2 Used $68.3 \div 4 = 17.05$

CO_2 3.70

Temperature 18.5°

Correction factor .938

Uncorrected volume 75.8

Max. HR 32

Work load 23°

Date 1-29-71

Corrected volume 71.10

True O_2 .0395

Max. $\dot{V}O_2$ 2.81 L

Kg. weight 59.55

ml/kg/min 47.19

The Capnograph CO_2 analyzer was calibrated before each testing period, and during the testing after about every fifth subject by the investigator. The Beckman O_2 analyzer was checked for accuracy by the investigator, but never calibrated by him, as this had been done previously by trained laboratory assistants. The treadmill was calibrated each testing period before use. The mouth piece and the tubing connecting the collection system were checked before each testing period. The oxygen bags were visually checked for leaks before use; however, some problems did occur with these bags.

During the pretest, there were five subjects tested in which there was evidence of a leaking oxygen bag. Two subjects were retested after a few minutes rest, using another bag, and substantially different oxygen uptake scores in ml/kg/min were obtained. The other three subjects were retested from one to three days later, and again the scores were substantially different. Two subjects who showed no evidence of error in testing were retested within three days (as a check on the procedures used by the investigator), and their scores were very nearly the same on retest as on the original test.

During the posttest, six members of the control and two members of group two showed evidence of a testing error, again a leaking oxygen bag being suspect. A retest on three members of the control and the group two subjects produced substantially different scores. One member of the control was not retested due to an ankle injury sustained during a baseball game occurring between the two tests. Two other control subjects were lost due to an oversight on the part of the investigator.

In the final analysis it was felt that reliable scores were obtained as a retest was done each time there appeared to be a suspicious result. Furthermore, average scores obtained in the study are in line with those average scores discussed in the literature (Table 3).

Daily Practice Sessions

There were thirty daily practice sessions held during the six weeks period of training. On practice day twenty-three, practice was called off because of heavy rainfall. Another day of practice was added to the end of the six weeks so that a total of thirty team practice sessions were held.

Missed practices by individual subjects were made up every Saturday morning under the supervision of the investigator. At these times each subject accomplished the workout which had been given on the day on which he had missed practice. Two experienced track men were allowed to make up one additional missed practice on Sunday without supervision. It was determined that should a subject miss five practices and be unable to make these up, he would be dropped from the study. One student missed four consecutive days due to illness during the fourth and fifth weeks and he was allowed to make these days up at the end of the practice sessions, taking his posttests approximately one week after the majority of the other subjects. Another subject missed four practices as he was a member of the tennis team and had team matches on practice days;

Table 3. Comparison of Average Scores for Males on the Oxygen Uptake Test

Researcher	Age of subjects in years	ml/kg/min
Metz and Alexander (36, 37)	12, 13	50.88
Metz and Alexander (36, 37)	14, 15	53.26
Present study	16.4	55.76
Åstrand (5)	17	59.2
Åstrand (5)	18	61.6
Åstrand (5)	19	61.3
Hermansen and Anderson (28)	21-26 (Athletes)	71.0
Hermansen and Anderson (28)	21-26 (Sedentary)	44.0

however, he was able to complete the program. The twenty-one subjects in the experimental groups averaged missing 1.7 sessions of the thirty practice sessions for a variety of reasons, ranging from college campus visitations to illnesses and slight physical injuries.

Practice of the control group consisted of the regular baseball practice plus an 880 yard jog at the conclusion of each practice at the individual subject's desired pace.

The daily routine of practice for the experimental groups consisted of:

1. a warm-up period of approximately eight to ten minutes,
2. a twenty to thirty minute period of practice in which the subjects practiced their individual events, with the emphasis on neuromuscular skill rather than on speed or conditioning,
3. a jog of 880 yards to be run at a pace of three to three and one-half minutes, just prior to the beginning of,
4. the regular speed-conditioning workout which lasted from thirty to fifty minutes, depending on the amount of running to be accomplished, and the recovery rate of each subject, and,
5. an 880 yard warm down at each subject's desired pace.

As indicated previously, the daily distances run and the intensity of each run for members of both experimental groups were identical. The only variable was the recovery period. Each subject in group one rested between each bout of running until his heart rate returned to 148-152 beats/minute, while each subject in group two rested until he recovered to 120-124 beats.

The actual amount of distance run varied from day to day and week to week. The primary type of running used consisted of buildups and hollow sprints. For variety, speed play was used once, a series of ten one hundred yard dashes once, the performance test three times, and the distance of the full out sprint portion of the buildups and hollow sprints were varied. There were also two track meets held against rival high schools run during the training period. On these days, each subject was required to run a certain number of buildups after his last competitive event, to accomplish a typical practice day's work.

Even though a variety of practice sessions were used, the recovery of the heart rate was carefully controlled throughout each session. This was accomplished by having each running bout started and terminated at one particular position on the track. After running a specified distance designed to end at or near the starting position on the track, the subject walked to the starting position and rested by standing nearby. The investigator or one of the assistants continually counted fifteen second intervals by use of a stop watch so that the subjects would monitor their own heart rate. The counter would say "Mark, set, count" to begin the fifteen second period, and then "Stop" at the end of the period of time. When an individual had recovered to his prescribed rate, he immediately began his next running bout. For subjects in group one, the beginning of another running bout was indicated when the heart rate recovered to 38 or 37 beats/fifteen seconds (148-152 beats/minute). For subjects in group two, the beginning of another running bout was indicated when the heart rate recovered to 31 or 30 beats/fifteen seconds (120-124 beats/minute).

This procedure was easily learned and all subjects were encouraged to follow the procedure very carefully. Occasionally, the investigator counted the heart rate of a subject as a check for accuracy and also as a motivational technique. As previously noted, it was found necessary to drop one subject from the study because he consistently failed to follow this training procedure.

During the six weeks of training, subjects were asked to refrain from additional running and other strenuous physical activity.

CHAPTER IV

RESULTS

Hypotheses Tested

The eight null hypotheses tested in this study are listed below.

1. There will be no change in the maximum heart rate in group one, group two, or the control group as measured by the Sprint Performance Test.

2. There will be no difference in the change of maximum heart rate between group one and group two, group one and control, group two and control, or group one plus group two and the control group as measured by the Sprint Performance Test.

3. There will be no change in speed in group one, group two, or the control group as measured by times on the Sprint Performance Test.

4. There will be no difference in the change in speed between group one and group two, group one and control, group two and control, or group one plus group two and the control group as measured by times on the Sprint Performance Test.

5. There will be no change in the score achieved in the Harvard Step Test by group one, group two, or the control group.

6. There will be no difference in the change of score between group one and group two, group one and control, group two and control,

or group one plus group two and the control group on the Harvard Step Test.

7. There will be no change in the maximum oxygen uptake in group one, group two, or the control group as measured by the Oxygen Uptake Test.

8. There will be no difference in the change in maximum oxygen uptake between group one and group two, group one and control, group two and control, or group one plus group two and the control group as measured by the Oxygen Uptake Test.

In addition to the above hypotheses, the Pearson product-moment correlation coefficient was applied to the data to determine the relationships among the Harvard Step Test, the Sprint Performance Test, and the Oxygen Uptake Test.

Summary of the Findings

Data gathered in the pre-, mid-, and posttreatment tests were used to test hypotheses one through six. Data gathered on the pre- and posttreatment test were used to test hypotheses seven and eight.

Analysis of this data indicated that although each of the three groups showed a slight decrease there was no significant change in maximum heart rate as the result of the training.

A significant increase in speed was shown for both group one and group two as compared to the control group. When comparing increase of speed between group one and group two, no significance was shown although a trend did seem to develop favoring group one.

The data showed that all three groups made significant improvement on the scores achieved on the Harvard Step Test. Groups one and two improved on both the mid- and posttest, while the control group improved on the midtest and then scored slightly lower on the posttest. A significant difference in the improvement of scores was shown between group two and control favoring group two. When groups one and two were combined, a significant difference in improvement of score over control was also found.

The data further showed significant improvement in maximum oxygen uptake for all three groups. Group one and group two showed slightly greater improvement than control; however, the difference is not enough for statistical significance.

The Pearson product-moment correlation coefficient was applied to the data to determine relationships between the Harvard Step Test and the Sprint Performance Test, the Harvard Step Test and the Oxygen Uptake Test, and the Sprint Performance Test and the Oxygen Uptake Test. Fisher's transformation of r to z failed to establish significant statistical relationships at the 5 percent level of confidence between the Harvard Step Test and Sprint Performance Test, and Sprint Performance Test and Oxygen Uptake Test. Relationship is found between the Harvard Step Test and the Oxygen Uptake Test among group one and group two subjects.

The results of testing each hypothesis are presented in the following pages.

Analysis of the Hypotheses

Hypothesis 1

There will be no change in the maximum heart rate in group one, group two, or the control group as measured by the Sprint Performance Test.

The mean maximum heart rates at the beginning of the training period were 191.4 for group one, 193.1 for group two, and 188.2 for control. At the completion of the six weeks of training group one had dropped 3.0 beats/minute to 188.4, group two had dropped 4.4 beats/minute to 188.7, and the control group had dropped 1.1 beats/minute to 187.1. The mean maximum heart rate for the three groups combined was 190.9 beats/minute at the beginning of the study and 188.1 at the end of the training period.

Of the thirty-two subjects tested, twelve showed an increase, fourteen a decrease, and six remained unchanged in maximum heart rate. In the two experimental groups, seven showed an increase, eleven a decrease, and three remained the same.

A one-way analysis of variance (ANOVA) was done on the data collected and no significant difference was found in any of the three groups (Table 4). The ANOVA failed to reject the null hypothesis that there will be no change in the maximum heart rate in group one, group two, or control as measured by the Sprint Performance Test.

Hypothesis 2

There will be no difference in the change of maximum heart rate between group one and group two, group one and control, group two and control, or group one plus group two and control as measured by the Sprint Performance Test. As shown above, no significant change in maximum heart rate was found when using the ANOVA; therefore, statistical procedure has failed to reject null hypothesis 2.

Table 4. Summary of ANOVA of Maximum Heart Rate

Subjects	Source	SS	DF	MS	F	Needed for significance
Control group	Between	.19	2	.095	.025*	3.31
	Within	112.36	30	3.74		
	Total	112.55	32			
Group one	Between	1.87	2	.935	.290*	3.35
	Within	85.50	27	3.17		
	Total	87.37	29			
Group two	Between	5.09	2	2.55	.761*	3.31
	Within	100.55	30	3.35		
	Total	105.64	32			

*No significant change.

Hypothesis 3

There will be no change in speed in group one, group two, or the control group as measured by times on the Sprint Performance Test.

The mean times in seconds on the pretest were 66.9 for group one, 65.07 for group two, and 71.19 for control. After three weeks of training, mean times on the midtest were 65.37 for group one, 64.11 for group two, and 71.03 for control. The posttest showed mean times of 63.46 for group one, 62.82 for group two, and 71.01 for control. These times represented a .82 second decrease at the midpoint and a 2.72 decrease on posttest for group one, a .96 second decrease at midpoint and a 2.25 decrease on the posttest for group two, and a .16 second decrease at midpoint and a .18 decrease on the posttest for the control group.

An ANOVA of the data showed a significant improvement in speed as measured by times for group one and group two and no increase in speed for the control group (Table 5).

Table 5. Summary of ANOVA for Change in Times on the Sprint Performance Test

Subject	Source	SS		DF		MS	F	Needed for significance
Control group	Between		544.00		10			
	Within		34.06		22			
	Treatment	0.13		2		.06	0.04	3.49
	Residual	33.94		20		1.70		
	Total		578.06		32			
Group one	Between		377.88		9			
	Within		57.69		20			
	Treatment	38.94		2		19.47	18.69*	3.55
	Residual	18.75		18		1.04		
	Total		435.56		29			
Group two	Between		148.63		10			
	Within		44.38		22			
	Treatment	28.13		2		14.06	17.31*	3.49
	Residual	16.25		20		0.81		
	Total		193.00		32			

*Significant at the .05 level.

Scheffé's procedure was used to locate points of significance. It was found that in group one there was no significant increase in speed from pretest to the midtest. Significant improvement at the five percent level of confidence was found between the pretest and the posttest and from the midtest to the posttest. There was no significant improvement in group two from the pretest to the midtest; however, significant improvement at the five percent level of confidence was found between the pretest and the posttest and between the midtest and the posttest.

Therefore, the hypothesis that there will be no change in speed in groups one, two, or control as measured by times on the Sprint Performance Test is rejected.

Hypothesis 4

There will be no difference in the change in speed between group one and group two, group one and control, group two and control, or group one plus group two and control as measured by times on the Sprint Performance Test.

Both the experimental groups showed an increase in speed between the pre- and posttreatment scores, and the mid- and posttreatment scores. Group two showed the greater gain of the two groups from the pre- to the midtest, while group one showed the greater gain from mid- to posttest and in overall gain from pre- to posttest. The application of Scheffé's procedure to the data failed to show significant differences in these changes.

A trend seems to occur when the data are examined closely. At the beginning of the study, the mean time for group two was better than the time for group one by 1.12 seconds. At the end of the study, the difference between the two groups was only .64 seconds, which showed a net gain of .48 seconds of group one over group two. As a tenth of a second may be important in track competition, this point is further discussed in Chapter V.

The ANOVA showed that there was a significant difference in mean speed between group one and the control group before the study began. Logically, this is to be expected as good speed is a must for successful sprinting ability in track, and good speed is not necessarily needed for successful participation in certain positions in baseball. The application of Scheffé's procedure further revealed that group one improved significantly over control between the mid- and posttreatment tests, and between pre- and posttest (Table 6). At the beginning of the study, the time for group one was better than the time for control by 5.00 seconds. After three weeks of training, this had increased to 5.66 seconds, and at the end of the study the difference was 7.55 seconds, representing a net gain of 2.55 seconds of group one over control on the Sprint Performance Test.

There was also a significant difference between group two and control before the study began. Since the ANOVA had shown a significant change in speed for group two, Scheffé's procedure was applied to find significant differences between group two and control from pre- to midtest, mid- to the posttest, and from the pre- to the posttreatment tests (Table 6). The pretest showed the times for group two to be 6.12 seconds better than control at the beginning of the study. At midtest this difference had increased to 6.93 seconds and on posttest the difference had grown to 8.19 seconds, representing a net gain of 2.07 seconds of group two over control.

Table 6. Means and Differences of Changes in Seconds on the Sprint Performance Test

Group	Pre-test	Mid-test	Difference	Mid-test	Post-test	Difference	Pre-test	Post-test	Difference	Needed for significance
CG	71.19	71.03	.16	71.03	71.01	.02	71.19	71.01	.18	1.82
G1	66.19	65.37	.82	65.37	63.46	1.90*	66.19	63.46	2.72*	1.40
G2	65.07	64.11	.96	64.11	62.82	1.29*	65.07	62.82	2.25*	.99
G1 + G2	65.60	64.71	.89*	64.71	63.12	1.59*	65.60	63.12	2.47*	.72
GC vs G1			.67			1.88*			2.54*	.82
GC vs G2			.81*			1.27*			2.07*	.80
G1 vs G2			.14			.61			.47	.82
GC vs G1 + G2			.74*			1.54*			2.29*	.30

*Significant at the .05 level.

Combining the two experimental groups and comparing these with control showed a significant difference existing before the study began. Application of Scheffé's procedure revealed a significant increase of speed for the experimental groups over the control from pre- to mid-, mid- to post-, and from pre- to posttreatment on the Sprint Performance Test (Table 6). The pretest showed a mean difference of 5.59 seconds between the control and the experimental groups favoring the latter group. By midpoint in the treatment, this difference had increased to 6.33 seconds, and on the posttest, the difference was found to be 7.88 seconds, representing a net increase of 2.29 seconds.

Therefore, the null hypothesis that there will be no difference in the change in speed between group one and group two, group one and control, group two and control, or group one plus group two and the control group as measured by times on the Sprint Performance Test is rejected.

Hypothesis 5

There will be no change in the score achieved in the Harvard Step Test by group one, group two, or the control group.

The mean score for the Harvard Step Test prior to treatment was 83.36 for control, 79.20 for group one, and 78.36 for group two. After three weeks of training, mean scores on the midtest were 88.55 for control, 84.90 for group one, and 87.00 for group two. On the posttest, mean scores were 88.18 for control, 87.00 for group one, and 89.36 for group two. These scores represented a 5.19 increase at midpoint and a 4.82 increase on posttest for control, a 5.70 increase at midpoint and a 7.80 increase on posttest for group one, and an 8.64 increase at midpoint and an 11.00 increase at posttest for group two.

A one-way ANOVA indicated that there was a significant increase in score on the Harvard Step Test in all three groups (Table 7). Scheffé's procedure was used to locate points of significance. It was found with the control that a significant increase was attained from the pretest to the midtest. From the midtest to the posttest there was a mean decrease of .37 in score. Interestingly, this decrease was sufficient to show no significant gain in the Harvard Step Test from the pre- to posttreatment score. For group one a significant gain in score at the five percent level of confidence was shown from the pretest to the midtest, and from pretest to the posttest. The small gain from midtest to posttest was not significant at the five percent level of confidence. Group two followed the same pattern as group one, showing no significance from midtest to posttest, but showing a significant gain in score from the pre- to midpoint, and from the pre- to posttest.

Therefore, the null hypothesis that there will be no change in the score achieved in the Harvard Step Test by group one, group two, or the control group is rejected.

Hypothesis 6

There will be no difference in the change of score between group one and group two, group one and control, group two and control, or group one plus group two and the control group on the Harvard Step Test.

As previously indicated, group one and group two followed a similar pattern on the Harvard Step Test score. Both showed the larger significant gain occurring from the pretest to the midtest, with a smaller but nonsignificant increase continuing from the midtest to the posttest. Both also showed an overall significant gain from pre- to posttest. Group two showed the greater gain between each of the tests;

Table 7. Summary of ANOVA for Scores on the Harvard Step Test

Subjects	Source	SS		DF		MS	F	Needed for significance
Control group	Between		1,043.00		10			
	Within		618.00		22			
	Treatment	184.06		2		92.03	4.24*	3.49
	Residual	433.94		20		21.70		
	Total		1,661.00		32			
Group one	Between		1,752.31		9			
	Within		568.00		20			
	Treatment	325.81		2		162.91	12.11*	3.55
	Residual	242.19		18		13.45		
	Total		2,320.31		29			
Group two	Between		807.38		10			
	Within		1,219.38		22			
	Treatment	737.63		2		368.81	15.31*	3.49
	Residual	481.75		20		24.09		
	Total		2,026.75		32			

*Significant at the .05 level.

however, Scheffé's procedure failed to show a significant difference existing in the change of scores between group one and group two on the Harvard Step Test.

The ANOVA showed that both group one and control made significant gain from the pretest to the midtest. At midpoint the control seemed to level off and actually had a decrease in score from midpoint to posttest to the degree that there was no overall significant gain from the pretraining test to the posttraining test. There was significant gain with the group one from pre- to posttest score. Even though group one showed a greater gain in score, Scheffé's procedure failed to show significant differences between the two groups in change in score. The pretest showed a difference of 4.16 existing between the scores favoring the control group. At midpoint, this score had dropped slightly to a difference of 3.65, and as group one continued to improve and control had a slight decrease, the posttest score revealed a difference of only 1.19 still favoring the control group. The overall gain of group one over control being 2.97 points from pretest to posttest on the Harvard Step Test score (Table 8).

By applying Scheffé's procedure to the difference in increase of score between the control group and group two, significant improvement is found from pre- to mid-, mid- to post-, and pre- to posttest for group two over control. The pretest showed a difference of 5.00 points existing between the score favoring the control group. The difference dropped to 1.55 at the midtest and then continued until there was a 1.18 difference favoring group two at posttest. The overall gain of group two over control being 6.18 points on the Harvard Step Test score (Table 8).

Table 8. Means and Differences in Changes of Score on the Harvard Step Test

Group	Pre-test	Mid-test	Difference	Mid-test	Post-test	Difference	Pre-test	Post-test	Difference	Needed for significance
GC	83.36	88.55	5.18*	88.55	88.18	-.37	83.36	88.18	4.82	5.12
G1	79.20	84.90	5.70*	84.90	87.00	2.10	79.20	87.00	7.80*	4.25
G2	78.36	87.00	8.64*	87.00	89.36	2.36	78.36	89.36	11.00*	5.39
G1 + G2	78.76	86.00	7.23*	86.00	88.24	2.24	78.76	88.24	9.47*	3.29
GC vs G1			.52			2.46			2.97	3.37
GC vs G2			3.46*			2.73			6.17*	3.28
G1 vs G2			2.94			.26			3.20	3.37
GC vs G1 + G2			2.05*			2.60*			4.65*	1.25

*Significant at the .05 level.

When the two experimental groups are combined and compared with control, significant differences in the increase of score is found from pre- to mid-, mid- to post-, and also from pre- to posttest scores on the Harvard Step Test. The difference between the combined score of group one plus group two and control move from 4.60 points in favor of control at pretest to .05 points favoring the experimental groups at posttest.

Therefore, the null hypothesis that there will be no difference in the change of score between group one and group two, group one and control, group two and control, and group one plus group two and the control group on the Harvard Step Test is rejected.

Hypothesis 7

There will be no change in the maximum oxygen uptake in group one, group two, or the control group as measured by the Oxygen Uptake Test.

The control started with a mean oxygen uptake of 46.22 ml/kg/min and increased 5.84 to 52.06 ml/kg/min from pre- to posttest. Group one began the study with a mean oxygen uptake of 49.30 ml/kg/min on pretest and increased 8.26 to 57.56 ml/kg/min on posttest. Group two began the study with a mean oxygen uptake of 48.27 ml/kg/min on pretest and increased 8.60 to 56.87 ml/kg/min on posttest. Student's t test was applied to the difference of means and significant improvement was found for all three groups (Table 9).

Therefore, the null hypothesis that there will be no change in the maximum oxygen uptake in group one, group two, or the control group as measured by the oxygen uptake test is rejected.

Table 9. Summary of Student's t Test for Maximum Oxygen Uptake

Subject	N	Means Pre	Means Post	SD Pre	SD Post	DF	t	Needed for significance
Control group	8	46.22	52.06	5.06	5.07	7	5.28*	2.36
Group one	10	49.30	57.56	10.22	6.60	9	5.05*	2.26
Group two	11	48.27	56.87	5.43	3.80	10	7.21*	2.23

*Significant at the .05 level.

Hypothesis 8

There will be no difference in the change in maximum oxygen uptake between group one and group two, group one and control, group two and control, or group one plus group two and the control group as measured by the Oxygen Uptake Test.

The application of Scheffé's procedure to the increases in ml/kg/min found in the three groups failed to show significant statistical difference among the three groups. Both experimental groups, however, showed a larger increase in ml/kg/min than did the control groups. Group one gained 2.42 ml/kg/min more than control and group two gained 2.76 ml/kg/min more than control between the pre- and posttraining tests (Figure 1). This difference is sufficient to merit further discussion in Chapter V.

The statistical differences are such that they fail to reject the null hypothesis that there will be no difference in the change in maximum oxygen uptake between group one and group two, group one and control, group two and control, or group one plus group two and the control group as measured by the Oxygen Uptake Test.

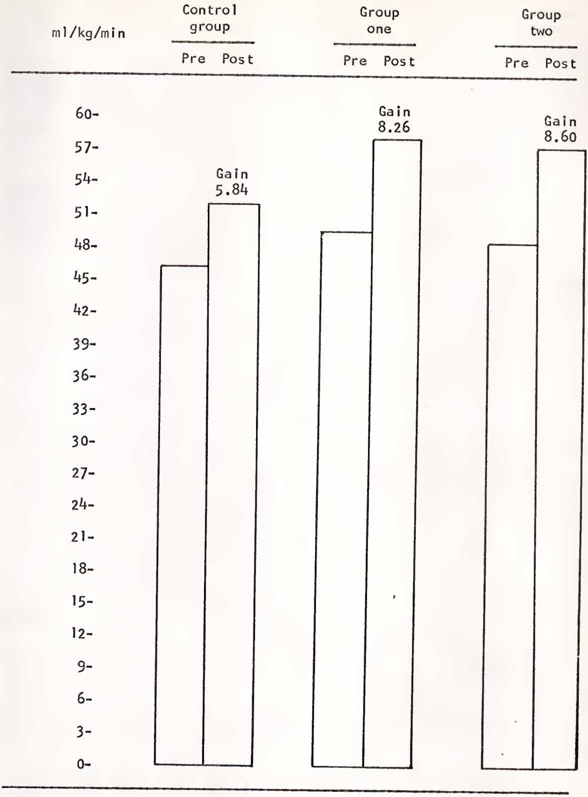


Figure 1. Mean Gain in ml/kg/min on the Oxygen Uptake Test

Relationships Among the Harvard Step Test, Sprint Performance Test, and Oxygen Uptake Test

The Pearson product-moment correlation coefficient was applied to the data to determine relationship between the Harvard Step Test and the Sprint Performance Test, Harvard Step Test and Oxygen Uptake Test, and Sprint Performance Test and Oxygen Uptake Test. The matrix for scores on the data is found in Tables 10, 11, and 12. Confidence intervals at the 95 percent level of confidence was established by use of Fisher's transformation of r to z.

Table 10 shows significant relationship between pre-, mid-, and post Sprint Performance Test, mid- and post Harvard Step Test, and pre- and post Oxygen Uptake Test for the control group. No significant correlations were found between Harvard Step Test and Sprint Performance Test, Harvard Step Test and Oxygen Uptake Test, and Sprint Performance Test and Oxygen Uptake Test for the control group.

Table 11 shows significant relationship between pre-, mid-, and post Sprint Performance Test, pre-, mid-, and post Harvard Step Test, and pre- and post Oxygen Uptake Test for group one. A significant correlation was found between post Harvard Step Test and pre- and post Oxygen Uptake Test. No significant correlation was found between the Sprint Performance Test and Harvard Step Test, and Sprint Performance Test and the Oxygen Uptake Test for group one.

Table 12 shows significant relationship between pre-, mid-, and post Sprint Performance Test, mid- to post and pre- to post Harvard Step Test, and pre- and post Oxygen Uptake Test for group two. The posttest for the Harvard Step Test and the pretest of the Oxygen Uptake Test were also found to be statistically related. No significant correlation was found between the Harvard Step Test and the Sprint Performance Test or between the Sprint Performance Test and the Oxygen Uptake Test for this group.

Table 10. Correlation Coefficients for the Control Group

Tests	SPT-PRE 1	SPT-MID 2	SPT-POST 3	HST-PRE 4	HST-MID 5	HST-POST 6	VO_2-PRE 7	VO_2-POST 8
SPT-PRE 1	--	0.8859*	0.9057*	-0.1766	-0.4339	-0.5228	0.2517	0.0983
SPT-MID 2	0.8859*	--	0.9758*	-0.5810	-0.4652	-0.5041	-0.1015	-0.3620
SPT-POST 3	0.9057*	0.9768*	--	-0.3998	-0.4131	-0.4233	-0.0551	-0.1019
HST-PRE 4	-0.1766	-0.4810	-0.3998	--	0.4985	0.5139	0.5525	0.5774
HST-MID 5	-0.4339	-0.4652	-0.4131	0.4985	--	0.8432*	0.2762	0.3433
HST-POST 6	-0.5228	-0.5041	-0.4233	0.5139	0.8432*	--	0.2080	0.3580
VO_2-PRE 7	0.2517	-0.1015	-0.0551	0.5525	0.2762	0.2080	--	0.8091*
VO_2-POST 8	0.0983	-0.3620	-0.1019	0.5774	0.3433	0.3580	0.8091*	--

Needed for significance: Items 1 through 6 0.5529
Items 7 and 8 0.6319

*Significant at the .05 level.

Table 11. Correlation Coefficients for Group One

Tests	SPT-PRE 1	SPT-MID 2	SPT-POST 3	HST-PRE 4	HST-MID 5	HST-POST 6	VO_2-PRE 7	VO_2-POST 8
SPT-PRE 1	--	0.9381*	0.8896*	-0.2430	-0.2004	-0.2367	-0.3581	-0.2869
SPT-MID 2	0.9381*	--	0.9820*	-0.1405	0.0323	-0.0474	-0.2442	-0.1678
SPT-POST 3	0.8896*	0.9820*	--	-0.0144	0.1292	0.0747	-0.1232	-0.0619
HST-PRE 4	-0.2430	-0.1405	-0.0144	--	0.7806*	0.8458*	0.4639	0.3660
HST-MID 5	-0.2004	0.0323	0.1292	0.7805*	--	0.8411*	0.2274	0.2698
HST-POST 6	-0.2367	-0.0474	0.0747	0.8458*	0.8411*	--	0.5784*	0.6021*
VO_2-PRE 7	-0.3581	-0.2442	-0.1232	0.4639	0.2274	0.5784*	--	0.8983*
VO_2-POST 8	-0.2869	-0.1678	-0.0619	0.3660	0.2698	0.6021*	0.8983*	--

Needed for significance: 0.5760

*Significant at the .05 level.

Table 12. Correlation Coefficients for Group Two

Tests	SPT-PRE 1	SPT-MID 2	SPT-POST 3	HST-PRE 4	HST-MID 5	HST-POST 6	VO_2-PRE 7	VO_2-POST 8
SPT-PRE 1	--	0.8500*	0.8796*	0.2129	-0.5495	-0.1218	-0.0986	-0.2397
SPT-MID 2	0.8500*	--	0.9102*	0.0955	-0.4641	-0.4008	-0.3533	-0.2896
SPT-POST 3	0.8796*	0.9102*	--	0.2514	-0.3833	-0.2080	-0.2174	-0.2192
HST-PRE 4	0.2129	0.0966	0.2514	--	0.3462	0.5761*	0.4143	0.3868
HST-MID 5	-0.5495	-0.4641	-0.3833	0.3462	--	0.5896*	0.5105	0.4061
HST-POST 6	-0.1218	-0.4008	-0.2080	0.5751*	0.5896*	--	0.8447*	0.4516
VO_2-PRE 7	-0.0986	-0.3533	-0.2174	0.4143	0.5105	0.8447*	--	0.6850*
VO_2-POST 8	-0.2397	-0.2896	-0.2192	0.3863	0.4061	0.4516	0.6850*	--

Needed for significance: 0.5529

*Significant at the .05 level.

CHAPTER V

DISCUSSION OF FINDINGS

Maximum Heart Rate

Even though no significant difference was found in change of the maximum heart rate, each of the three groups showed a slight decrease at the completion of the six weeks period of training. This slight but nonsignificant difference in maximum heart rate may be attributed to one of three possible explanations, the factor of regression, the lapse of time between pre- and posttest, or the effect of training on the maximum heart rate.

Group two had the highest maximum heart rate in the pretest and also the greatest drop of heart rate, 4.4 beats/minute. The control group had the lowest maximum heart rate in pretest, and the least amount of change, 1.1 beats/minute. As indicated, the factor of regression could possibly account for these changes.

It has been demonstrated by Åstrand and others (4) that the maximum heart rate drops with age from about 210 at age ten to about 160 beats/minute in the sixties. It is possible that such a slight decrease as found in this study could occur in the seven weeks of time which elapsed between the pre- and posttreatment tests.

Another possibility is that the intensive training in which the experimental groups engaged as compared to the control group did cause a decrease in maximum heart rate for the experimental groups. There is no significant difference found here, however, and the results of the training on maximum heart rate must be found to be inconclusive in this study.

Another interesting point is found in the overall pre- and post means of maximum heart rate in this study as compared to those found by Wyndham (47), and Metz and Alexander (36, 37). Metz and Alexander, in testing sixty boys selected at random from physical education classes, found the mean maximum heart rate for the twelve and thirteen year olds to be 199 beats/minute, and the fourteen and fifteen year old boys to be 196 beats/minute. Wyndham found forty young army recruits to have a mean maximum heart rate of 196 beats/minute (47). The mean maximum heart rate for the subjects in this study was 190.9 beats/minute in pretest and 188.1 on posttest. The mean age was sixteen years, five months. The average maximum heart rate in this study is somewhat lower than those found by Wyndham and by Metz and Alexander. This may be explained in the physical makeup of the subjects in these studies. The subjects used by Wyndham and by Metz and Alexander were drawn at random from their respective selected populations, and probably represent a cross section of young men and boys containing athletic as well as nonathletic subjects. The subjects used in this study were chosen exclusively from varsity high school athletic teams and were therefore made up of subjects with an athletic background. The lower mean maximum heart rate of these subjects would indicate that training associated with athletics does tend to lower the maximum heart rate of teenage boys.

Change in Speed

A one-way ANOVA of the data indicated that there was no significant change in the speed of the control subjects throughout the six weeks of training. Since these subjects were members of the varsity baseball team and practiced the skills specific to that sport, they did not engage in any speed work per se. Only at times when speed was necessary to carry out a team assignment, such as shagging a fly ball, or running the bases, did subjects run at full speed.

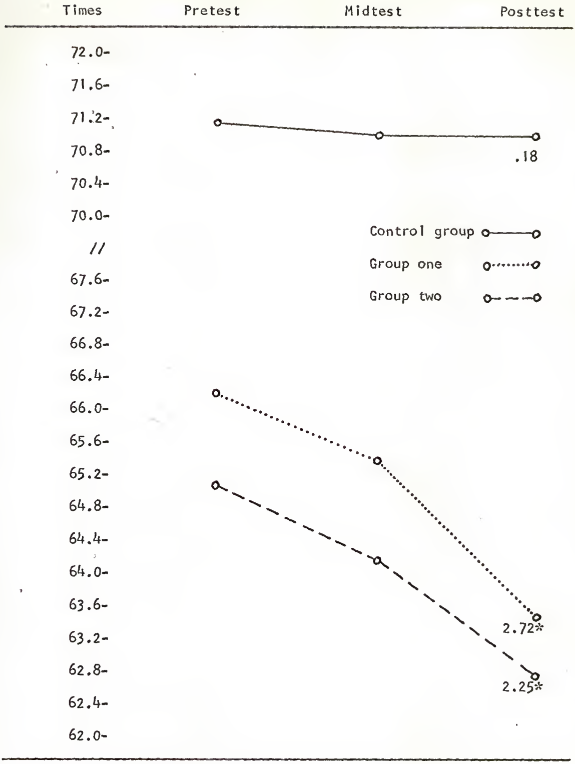
The ANOVA revealed that both group one and group two showed an increase in speed as indicated by improvement of times on the Sprint Performance Test. In both these groups there was significant increase shown between the pre- and posttests and between the mid- and posttests. Although significance was not shown at the end of the first three weeks of training, both of these groups had decreased times of almost a full second. Group one showed a .82 decrease and group two had a .96 second decrease in time. This decreased time, which indicates an increase in speed, continued the final three weeks of training with group one further improving its time by 1.90 seconds, and group two improving by 1.29 seconds.

It should be recalled that the method of training utilized by the two experimental groups consisted of repetitions of short sprints run at full speed interspaced by a period of rest based on each subject's recovery heart rate. The findings indicate that this method of training did have a significant effect upon increase in speed in both experimental groups, whereas little increase in speed was noted with the control group.

The difference in change of speed between group one and group two failed to indicate significance. However, a trend does seem evident. The mean times at the beginning of the study and on the mid test showed a .14 second increase of group two over group one; however, between mid- and posttest the difference was reversed with group one showing an increase of .61 seconds over group two. The overall change for group one during the six weeks of training was 2.72 seconds and for group two the change was 2.25, or a total gain of .48 seconds of group one over group two. Furthermore, there was no leveling off of the increase of speed between pre- and mid-, and mid- and posttest for either group. In fact, the opposite is indicated in the downward curve of decreased times (Figure 2). This would indicate, that had training continued, a further increase of speed was likely, and had the trend continued in favor of group one, a significant difference in change of speed could have occurred favoring this group of subjects.

Even though a statistically significant difference is not indicated, the slight improvement of group one over group two does have significance for the track coach in economy of time spent in practicing the sprints. Group one used a recovery heart rate of approximately 150 beats/minute as contrasted to a heart rate of approximately 120 beats/minute for group two. The actual time spent in recovery between running bouts was, therefore, shorter for most of the group one subjects than for the group two subjects. The time saved in a shorter recovery period could be used by the individual runner to practice another track event, such as starts, relay handoffs, and the like.

Since no statistical difference is found between the two experimental groups in change in speed, this would bear out the



*Significant at the .05 level.

Figure 2. Mean Improvements in Time Changes on the Sprint Performance Test

assumption that recovery of the heart rate of 150 beats/minute provides for sufficient rest for high school sprinters between short distance bouts of running.

Discussion of Individual Subjects

Figures 3 and 4 on the following pages show the results of the pre- and post Sprint Performance Test for each subject. Some interesting points are indicated for discussion although no conclusions can be definitely drawn from this information.

The two subjects who had the best times on the pretest also showed best times on the posttest. The best sprinter showed an improvement of only .2 seconds and the second best sprinter improved by 1.4 seconds, well below the mean gain for their respective groups. Investigation of these two subjects revealed that they were both Seniors who were in their fourth year as members of the varsity track team. Furthermore, both had run on the cross country team three months previous to this study, both were student assistants in physical education classes, and both did individual running workouts on a year-round basis. The probable reason for the small improvement in time for these two is that each was near his maximum speed at the beginning of the study.

Of the twenty-one subjects in the two track groups, one subject failed to improve. This subject did not finish the track season, and it is suspected that he was not properly motivated and did not give a full measure of effort in the practice sessions.

It might be expected that those subjects whose speed was poorer than the mean would improve at a greater rate than those whose speed was greater than the mean. The ten subjects whose times were poorer than the mean time at pretest showed an average gain of 2.65 seconds as

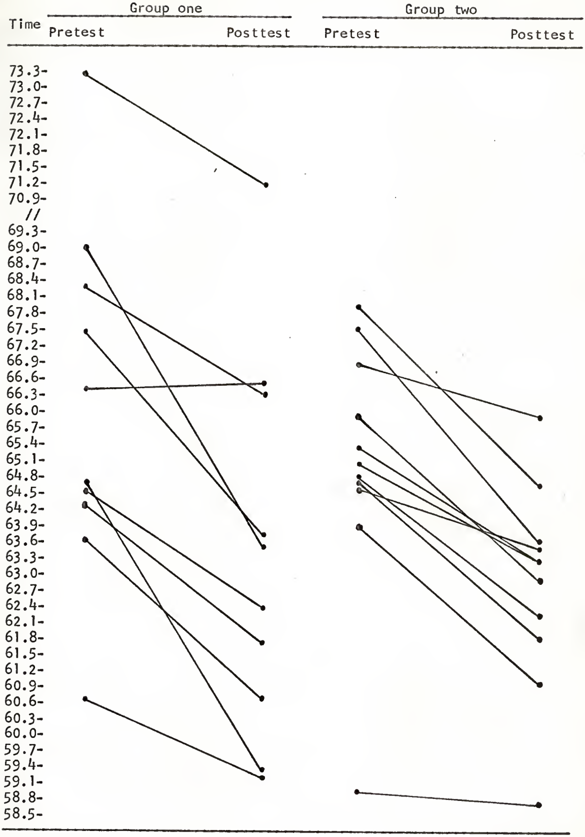


Figure 3. Changes in Time for the Experimental Subjects on Pre- and Post Sprint Performance Test

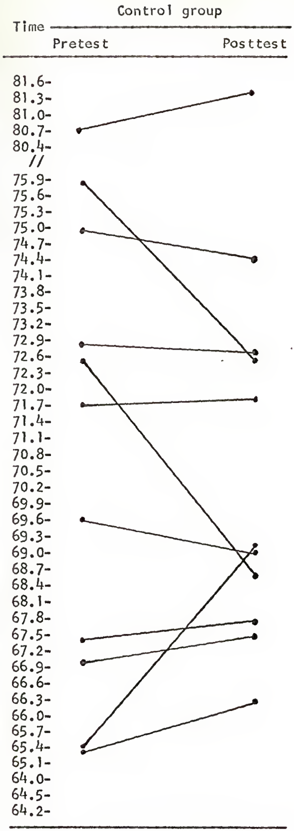


Figure 4. Changes in Time for the Control Subjects on Pre- and Post Sprint Performance Test

contrasted with a 2.54 seconds gain for the total of the two experimental groups. The difference is only .11 seconds which seems to refute this notion.

In the control group, two boys showed an improvement greater than the mean for the experimental groups, and one boy made a very poor showing. It is suspected that a recording error was made on the pretest of the boy who did poorly, as his mid- and post scores were only .4 second different. One of the two boys who showed good improvement was the number one varsity pitcher on the baseball team. This boy did a great deal of sprint work in addition to the regular baseball practice to condition his legs for pitching. No apparent explanation can be found for the good improvement of the other baseball player.

Figure 3 shows that the majority of the experimental subjects had very similar increases in speed with the exceptions already noted. The subjects in the control group (Figure 4) showed very small increases or decreases with exceptions noted. This indicates that the speed training, or lack of speed training, had similar effect on the change of speed of the subjects in the study.

The Harvard Step Test

The ANOVA of the data revealed that all three groups made a significant increase on score on the Harvard Step Test. Since the Harvard Step Test is based on the recovery of the heart rate, a significantly faster recovery of heart rate is evident for all groups in the study. This indicates that the intensity of training for the baseball group as well as for the two track groups was sufficient to cause a faster recovery of heart rate. The athlete who can recover faster from maximum work is able to continue to participate sooner than one who has a slower recovery heart rate.

The control group showed significant gain in the first three weeks of the study, and then for the last three weeks there was a slight decrease in the mean score for the group. This would indicate that the intensity of work in which this group was engaged was sufficient to cause a beneficial lowering of the recovery heart rate to a point at which there seemed to be a leveling off with no further gain (Figure 5). Continued work at the same degree of intensity had no further beneficial effect on the recovery of the heart rate.

Both group one and group two showed significant gain in the first three weeks of training. During the last three weeks gain in score on the Harvard Step Test continued, but not at a significant pace. There was not, however, a leveling off of gain in either of these two groups as was found with the control group. It is reasonable to assume that with further similar training of the two experimental groups, the recovery of the heart rate would have continued to some point at which a leveling off would have occurred.

In comparing group one with group two, group two showed greater gain which approached significance but did not show significant differences between the two groups. It should be remembered that this group of subjects recovered to approximately 120 beats/minute in practice as compared to 150 beats/minute for the subjects in group one. The recovery period for group two is similar to the recovery period used by many distance runners when training for competition (46). Distance runners have a lower resting heart rate and generally recover faster than sprinters (46). It is possible that the difference in the two

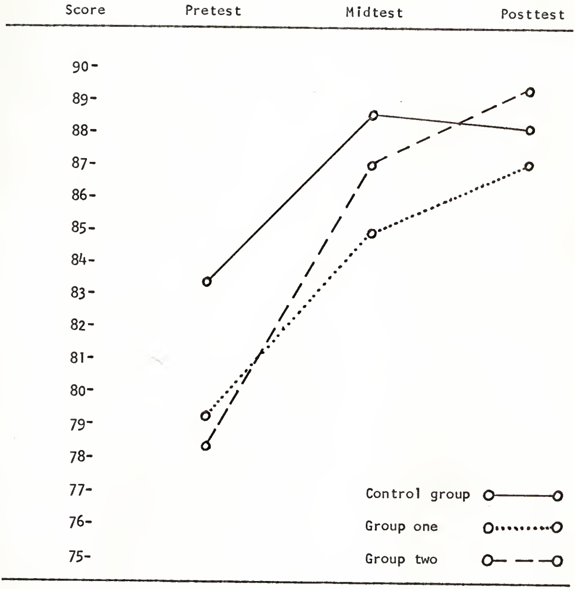


Figure 5. Mean Differences of Scores on the Harvard Step Test

recovery heart rates used in this study had bearing on the faster recovery of heart rate shown by group two; however, as no significant difference in the two groups is found, the results in relation to this question must remain inconclusive. Further study in this area for high school runners is indicated.

Group one showed considerable gain on control from pretest to posttest but significance was not reached. Group one began the study at 4.16 points below control and gained to a point of only 1.18 points difference in the six weeks of training. As stated previously, had the study continued, it is possible that group one would have eventually shown significant improvement over control.

Group two showed significant improvement over the control group from the pretest to midtest and from the pretest to the posttest. Pretest found this group with a score 5.00 points below that of control, and on posttest, even though both groups had shown significant improvement, group two had caught and surpassed the control group in mean score. Furthermore, no evidence of leveling is shown for group two subjects although control seems to have leveled off. Therefore, the intense training of group two, coupled with the recovery of the heart rate to approximately 120 beats/minute between bouts of running, had a significantly greater benefit in a faster recovery of the heart rate, than the training experienced by the control group.

When both track groups are combined and compared with the control group, a significant change on score of the Harvard Step Test during all periods of testing in the study is shown.

In summary, the intense training undergone by group one and group two, which became progressively more intense as training continued, had a significantly greater benefit in a faster recovery of heart rate than did the training received by the control group. Furthermore, there is some evidence that a recovery of approximately 120 beats/minute between bouts of running is of greater benefit in eliciting a faster recovery of heart rate than a recovery of 150 beats/minute.

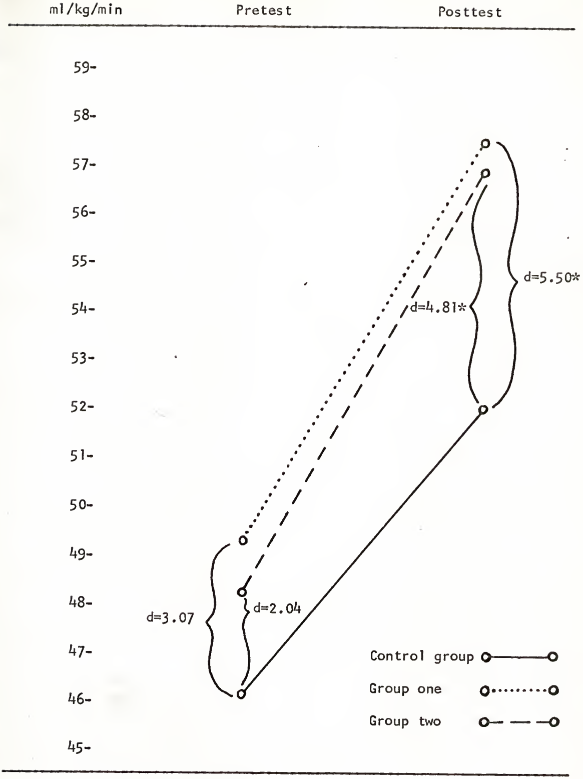
Oxygen Uptake

All three groups showed significant gain in oxygen uptake as measured by the pre- and post Oxygen Uptake Test.

This indicates that the physical activity in all groups was sufficient to provide for significant cardiovascular improvement among the subjects.

The two experimental groups showed a relatively similar gain in ml/kg/min with group two having a slightly higher mean gain. The different recovery heart rates used by these two groups apparently had little or no effect upon the gain of oxygen uptake when working at maximum heart rate.

Scheffé's procedure failed to show a significant difference in increase of oxygen uptake of group one and group two when compared to control. The mean of both group one and group two showed a gain of approximately 2.5 ml/kg/min more than the mean gain of control. ? Student's t test showed no significant difference between the two track groups and control before the study began although there was some apparent difference between groups one and two combined and the control group favoring the former (Figure 6). The intense training undertaken by groups one and two caused a greater growth in cardiovascular fitness among these two groups than was shown by the control group.



*Significant Difference

Figure 6. Differences in Mean Gain in ml/kg/min Between Group One and Control and Group Two and Control

Relationship Among the Harvard Step Test, Sprint Performance Test, and Oxygen Uptake Test

The pre- to mid-, mid-to post-, and pre- to posttest scores on the Sprint Performance Test for all three groups were found to be significant at the 5 percent level of confidence by using Fisher's transformation of the Pearson product-moment correlation coefficient r to z. This significant finding was expected. Speed is a physical component which changes little even with much practice. A small change in speed, however, has great importance in running short distance sprints up to 220 yards as each tenth of a second means almost one yard in distance traveled. As already pointed out, the pattern of change in speed was similar among subjects in group one and group two, and also among the control subjects, with a few notable exceptions previously discussed.

The pre- to posttest of Oxygen Uptake Test for all three groups were found to be significant at the 5 percent level of confidence by using Fisher's transformation of the Pearson product-moment correlation coefficient r to z. This indicates that the training obtained in each of the groups had significant similar effect upon the change in cardiovascular fitness upon the subjects in the group in which he participated.

The pre- to mid-, mid- to post-, and pre- to postscores on the Harvard Step Test for group one were found to be significant at the 5 percent level of confidence on the Pearson product-moment correlation coefficient matrix of scores, indicating similar patterns of beneficial lowering of the heart rate for this group as a result of training. For group two significance was found pre- to post- and mid- to post- on the Harvard Step Test. For the control group significance was found only from the mid- to posttest on scores on the Harvard Step Test. Since significance was not uniform for group two and control throughout the Harvard Step Test, some unexplained differences in patterns of change are evident for subjects in these two groups.

Significant relationships between the Harvard Step Test and the Oxygen Uptake Test were found in both group one and group two subjects. This would indicate a relationship between beneficial lowering of the recovery of the heart rate and an increase in cardiovascular fitness as measured by maximum oxygen consumption. Other studies which have used both the Harvard Step Test and maximum oxygen uptake show significant correlation between these two factors (27, 36).

CHAPTER VI

SUMMARY

The purpose of this study was to investigate the effectiveness of using the recovery of the heart rate as a means of determining the interval of rest which a high school sprinter requires between repetitions of running when training for competition.

Thirty-two subjects, all high school varsity athletes, were placed into three groups for study. The control group consisted of eleven baseball players chosen at random from the total squad who participated in a daily baseball practice of approximately two hours duration, plus an 880 yard run at each subject's desired pace at the conclusion of practice. The other two groups were made up of members of the track squad randomly placed and receiving identical daily practice sessions with one exception.

The practice sessions consisted of a type of interval training in which the distance of the run, the intensity of the run, the recovery action and postural position, and the number of repetitions accomplished in each practice session was the same for each subject. The groups differed only in the recovery period allowed between repetitions of running. Each subject in group one rested until his heart rate recovered to approximately 150 beats/minute, whereas the subjects in group two recovered to approximately 120 beats/minute.

It was assumed that the most efficient working threshold of high school runners occurred between a heart rate of 150 beats/minute and the maximum heart rate. Work done at less than 150 beats/minute was felt to be of little value to the sprinter in improving his speed and in being able to hold his times in subsequent sprints with limited recovery. Therefore, in practicing for competition by using short distance speed work, a recovery of 150 beats/minute was felt to provide sufficient rest between bouts of running.

Three physical working tests were given to all subjects to measure change in certain physical parameters. A Sprint Performance Test was designed by the investigator to measure change in speed. An Oxygen Uptake Test was used to measure change in maximum oxygen uptake as an indication of cardiovascular fitness. The Harvard Step Test was used to measure change in the recovery of the heart rate as an indication of cardiovascular fitness. The Sprint Performance Test and the Harvard Step Test were given prior to training, after three weeks of training, and after six weeks of training. The Oxygen Uptake Test was given to all groups prior to training and after six weeks of training. Furthermore, changes in the maximum heart rate were measured by the Sprint Performance Test. The relationships between the Harvard Step Test and the Sprint Performance Test, the Harvard Step Test and Oxygen Uptake Test, and the Sprint Performance Test and the Oxygen Uptake Test were also found.

Results

An ANOVA of the data revealed no significant change in the maximum heart rate.

An analysis of the Sprint Performance Test found significant improvement in times and speed for group one and group two but no change for the control group. Group one made a slightly greater improvement than group two but significant difference was not reached. The fact that group one did as well as group two indicated that a recovery of heart rate to 150 beats/minute was sufficient rest, insofar as improvement in speed is concerned, for high school sprinters between repetitions of running in training. This leads to economy of time in practice as a higher recovery heart rate allows the runner to return to the next running bout in a shorter period of time.

All three groups made significant improvement on the Harvard Step Test during the first three weeks of practice, indicating that the intensity of training for all groups to that point was sufficient to cause a beneficial faster recovery of heart rate. However, the control group had a loss of improvement between the midtest and the posttest to a level of no significance between pre- and post change in Harvard Step Test score. Group one and group two continued to improve the last three weeks of training. The training received by the control group was not sufficient to cause improvement in the last three weeks of training. The more intense training, which was also progressively increased, received by group one and group two was sufficient to show improvement throughout the six weeks of training, with no evidence of a leveling off of beneficial rate of the recovery of the heart. This continued improvement would support the assumption that the working threshold for a beneficial lowering of the heart rate occurs between a heart rate of 150 beats/minute and maximum, the rate at which group one and group two subjects worked during their practice sessions.

It should be emphasized again that group one maintained a heart rate of 150 beats/minute throughout the entire period of the workout. The subjects in group two accomplished the working portion of the workout at above 150 beats/minute; however, the heart rate did drop below 150 during the period of recovery. The extra time used in recovery from 150 to approximately 120 beats/minute was, therefore, of little or no value to the sprinter in this study.

On the Oxygen Uptake Test, all three groups showed a statistically significant increase in maximum oxygen intake, indicating that the intensity of work done for all three groups was sufficient to cause better oxygen consumption and therefore, improved cardiovascular fitness. Where no significant difference was shown on the pretest, significant difference between the control group and group one plus group two was found on the posttest, indicating that the more intense training undertaken by group one and group two caused a greater growth in cardiovascular fitness than the training received by the control group.

Pearson product-moment correlation coefficient revealed significant relationship between the Harvard Step Test and the Oxygen Uptake Test for group one and group two.

Recommendations

It is felt that this study would have been stronger had a longer period of training been utilized and tested. A study similar to this one lasting nine weeks rather than six weeks might answer some of the questions suggested in Chapter V. Specifically, would a greater increase in speed be attained by the group one subjects when compared to group two? Would the group two subjects continue to make greater gain in faster recovery of the heart rate than those in group one? At what point would a leveling off of faster recovery of the heart rate occur for groups one and two? What effect does intense training, such as used in this study, have on the maximum heart rate of high school track performers?

Another set of questions might be offered concerning the recovery heart rate used in this study. Would 140 beats/minute have been better than 150 as the top recovery period used? If the recovery of heart rate is an individual matter, would the use of a formula based on the individual's resting heart rate, maximum heart rate, and working heart rate be more precise than a set rate for all subjects at which to return to running?

More research is needed in the area of the use of the recovery of the heart rate in training programs for high school athletes.

Conclusions

On the basis of the findings of the study, the following conclusions are offered:

1. The use of the recovery heart rate to determine the interval of rest required by high school sprinters between bouts of running, represents a reliable method of controlling this factor of interval training.

2. A recovery of 150 beats/minute is sufficient for the high school sprinter between bouts of full speed running, if the distance of the run is kept short--from fifty to one-hundred-twenty yards.

3. An economy of time is gained when using a heart rate of 150 beats/minute as against 120 beats/minute. Time saved in completing the conditioning portion of the regular track practice can be used for practicing other valuable skills in track, such as starts, relay handoffs, hurdle work, long jump, and the like.

APPENDICES

APPENDIX A

The Daily Practice Sessions

The first practice was held on February 1, 1970, and the final practice was held on March 13, 1970. There were a total of thirty regular practice sessions during the six weeks period of training.

The practice regime consisted of five phases each day. These phases were practiced in the following order: (1) warm-up phase, (2) speciality period, (3) 880 yard warm-up jog, (4) the conditioning phase, and (5) 880 yard warm-down.

The warm-up period consisted of several selected calisthenics. A typical practice session warm-up consisted of:

1. ten jumping jacks,
2. ten wood choppers,
3. thirty push-ups, in sets of ten,
4. thirty bent leg sit-ups,
5. thirty spring-ups or spring-outs from thirty-six inches high,
6. ten hurdle stretchers on each leg, and
7. one minute of groanies.

The speciality period varied among the subjects. This period usually lasted about twenty minutes. Each subject practiced skills related to the events in which he participated in a track meet. This might include such things as discus spin and release, shot put form, high jump form, pole vault run through, long jump form, relay handoffs, starts, and timing and steps in the high and low hurdles. Emphasis was on skill development rather than on cardiovascular conditioning.

Just before beginning the intensive conditioning phase of the daily practice session, the subjects jogged 880 yards in three to three and one-half minutes.

On completing the 880 yard jog, the running schedule for the day was explained to all subjects. Heart rates were taken and the subjects then began the first intensive running bout of the day.

At the completion of the intensive portion of the practice session each subject jogged 880 yards at his desired pace as the final run of the day.

The Conditioning Phase

The intensive portion of the daily conditioning program consisted primarily of buildups and hollow sprints. Each buildup consisted of one lap (440 yards) around the track in the following manner: jog, stride out, sprint, walk, jog, stride out, sprint, walk. The track was therefore divided into eight parts of 55 yards each for a normal buildup. Toward the end of the study, the sprint portions were increased at the expense of the walking portions. For instance, should a 65 yard buildup be called for, the subject would jog 55 yards, stride 55 yards, sprint 65 yards, walk 45 yards, and then repeat those distances for one lap of 440 yards.

Hollow sprints consisted of one lap around the track in which the subject jogged, sprinted, jogged, and sprinted. The sprint portion of the run was enumerated in the directions to the subjects. A 110 yard hollow sprint, therefore, divided the track into four equal segments whereas a 90 yard hollow sprint called for a jog of 130 yards followed by a sprint of 90 yards which was repeated to accomplish the 440 yard lap.

In listing the thirty workouts it should be remembered that warm-up calisthenics, a speciality period of practice, and an 880 yard warm-up was accomplished prior to the conditioning phase. Furthermore, an 880 yard warm-down followed the intense workout. It should also be recalled that each subject recovered to his designated recovery heart rate between running bouts.

Practice day one - Four buildups of 55 yards.

Practice day two - Two buildups of 55 yards.

One hollow sprint of 110 yards.

Two buildups of 55 yards.

Practice day three - Sprint Performance Test given but not scored.

Two buildups of 55 yards.

Practice day four - Four hollow sprints of 90 yards.

Practice day five - Speed play, consisting of distances listed below.

Buildup followed by a 6:30 mile run.

Buildup followed by a 3:20 half-mile run.

Buildup followed by a 90 second 440 run.

Buildup followed by a 35-40 second 220 run.

Buildup followed by a full speed 100 yard dash.

Buildup.

Practice day six - Five buildups of 55 yards.

Practice day seven - One buildup of 50 yards first sprint, 60 yards second sprint.

One buildup of 70 yards first sprint, 80 yards second sprint.

One buildup of 90 yards first sprint, 100 yards second sprint.

Repeat each of the above.

Practice day eight - Four buildups of 55 yards.

Four hollow sprints of 110 yards.

Practice day nine - Ten full speed timed 100 yard sprints. Jog lap after each and recovery to proper heart rate.

Practice day ten - Three buildups of 55 yards.

Three hollow sprints of 90 yards.

Alternating laps. Buildups then hollow sprints.

Practice day eleven- Four buildups of 55 yards.

Three hollow sprints of 110 yards.

Alternating laps beginning and ending with buildups.

Practice day twelve- Same as eleven.

Practice day thirteen - Four hollow sprints of 110 yards.

Three buildups of 55 yards.

Alternating laps beginning with hollow sprints.

Practice day fourteen - Five buildups at 55 yards.

This was an easy day since the Sprint Performance test was to be given the following day.

Practice day fifteen - Midtest of the Sprint Performance Test.

Three buildups of 55 yards.

Practice day sixteen - Four buildups of 55 yards.

Four hollow sprints of 110 yards.

Practice day seventeen - Two buildups of 55 yards.

One 440 run in 90 seconds.

Two buildups of 55 yards.

One 440 run in 90 seconds.

One buildup of 55 yards.

Practice day eighteen - Track meet. Each subject competed in normal track meet events. Each event counted as one buildup. The practice consisted of six buildups, therefore, after each subject had completed his competition for the meet, he immediately ran a number of buildups to complete the six buildup requirement.

Practice day nineteen - Four buildups of 65 yards.

Three hollow sprints of 110 yards.

Alternating laps beginning and ending with buildups.

Practice day twenty- Same as nineteen.

Practice day twenty-one - Sprint Performance test given but not scored.

Four buildups of 55 yards.

Practice day twenty-two - Four buildups of 65 yards.

Three hollow sprints of 110 yards.

Alternating laps beginning and ending with buildups.

Practice day twenty-three - Four buildups of 60 yards.

Four hollow sprints of 110 yards.

Alternating starting with the buildups.

Practice day twenty-four - Two buildups of 60 yards.

One 440 in 80 seconds.

Repeat twice to accomplish three sets.

Practice day twenty-five - Track meet. Same as practice day eighteen.

Practice day twenty-six - Five buildups of 65 yards.

Four hollow sprints of 120 yards.

Alternating laps beginning and ending with buildups.

Practice day twenty-seven - Four buildups of 65 yards.

Three 220's at full speed plus two seconds.

Alternating laps starting with buildups.

Practice day twenty-eight - Five buildups of 65 yards.

Four hollow sprints of 120 yards.

Alternating laps beginning with buildups.

Practice day twenty-nine - Two buildups of 65 yards.

One hollow sprint on 120 yards.

Repeat twice to accomplish three sets.

Practice day thirty- Buildup of 65 yards.

Hollow sprint of 110 yards.

220 at full speed plus two seconds.

Repeat twice to accomplish three sets.

APPENDIX B

Maximum Heart Rate as Determined by the Sprint Performance Test

Control				Group one				Group two			
Subject	Pre	Mid	Post	Subject	Pre	Mid	Post	Subject	Pre	Mid	Post
1	174	186	180	12	192	192	204	22	204	204	192
2	204	180	180	13	186	180	180	23	174	180	180
3	168	174	174	14	204	204	192	24	186	180	186
4	192	204	198	15	180	174	168	25	186	180	186
5	186	192	198	16	180	186	186	26	198	186	180
6	180	174	168	17	186	186	192	27	186	192	180
7	204	210	210	18	204	198	186	28	192	174	180
8	192	192	192	19	204	216	186	29	210	186	198
9	192	180	180	20	192	198	198	30	210	210	216
10	186	186	186	21	186	186	192	31	192	186	180
11	192	186	192					32	186	186	192
Mean	188.2	187.6	187.1		191.4	192.0	188.4		193.1	187.6	188.7

APPENDIX C

Scores on the Harvard Step Test

Subject	Group	Pretest					Midtest					Posttest				
		R_1	R_2	R_3	Total	Sc	R_1	R_2	R_3	Total	Sc	R_1	R_2	R_3	Total	Sc
1	GC	69	61	55	185	81	67	58	56	181	83	65	58	58	183	82
2	GC	72	60	57	189	79	61	54	51	166	90	60	52	50	162	93
3	GC	68	60	55	183	82	61	56	51	168	89	61	53	53	167	90
4	GC	72	58	58	188	80	65	58	50	173	87	71	63	60	194	77
5	GC	68	59	57	184	82	64	59	55	178	84	70	62	57	199	75
6	GC	63	53	54	170	88	57	50	50	157	96	54	45	43	142	106
7	GC	62	51	49	162	93	63	56	50	169	89	64	55	50	169	89
8	GC	63	59	51	173	87	54	49	46	149	101	54	49	42	145	103
9	GC	69	59	55	183	82	64	55	53	172	87	67	57	53	177	85
10	GC	66	59	59	184	82	60	56	53	169	89	60	57	55	172	87
11	GC	69	61	55	185	81	69	64	56	189	79	65	60	56	181	83
12	G1	71	64	64	199	75	65	60	57	182	82	64	57	55	176	85
13	G1	72	66	63	201	75	68	60	53	181	83	66	59	52	177	85
14	G1	73	61	61	195	77	66	58	53	177	85	61	55	48	164	91
15	G1	58	49	45	152	99	58	51	50	159	94	54	47	45	146	103
16	G1	71	63	60	204	74	70	60	59	189	79	66	60	57	183	82
17	G1	65	59	57	181	83	64	62	55	181	83	67	60	54	181	83
18	G1	71	65	55	191	79	70	61	60	191	79	66	60	57	183	82
19	G1	78	69	64	211	71	66	61	55	182	82	63	56	54	173	87
20	G1	76	71	69	216	69	70	65	60	195	77	74	64	62	200	75
21	G1	61	55	50	166	90	54	46	43	143	105	56	50	49	155	97
22	G2	77	67	60	204	74	69	62	57	188	80	64	60	55	179	84
23	G2	67	63	57	187	80	60	54	51	165	91	59	53	54	166	90
24	G2	73	66	64	203	74	66	64	59	189	79	69	65	60	194	77
25	G2	67	60	54	181	83	65	62	56	183	82	66	60	57	183	82
26	G2	69	61	56	186	81	60	53	50	163	92	63	57	52	172	87
27	G2	69	64	62	195	77	62	52	48	162	93	60	54	52	166	90
28	G2	68	51	52	176	85	58	56	52	166	90	52	48	44	144	104
29	G2	77	69	63	209	72	60	56	54	170	88	65	60	57	182	82
30	G2	72	63	59	194	77	61	53	52	166	90	54	49	46	149	101
31	G2	67	60	57	184	82	69	54	48	171	88	54	47	45	146	103
32	G2	70	65	60	195	77	66	58	54	178	84	65	58	58	181	83

APPENDIX D

Sprint Performance Test Scores In Seconds

Subject	Control group											
	Pretest				Midtest				Posttest			
	110	200	220	Total	110	200	220	Total	110	200	220	Total
1	13.8	27.0	30.9	71.7	14.3	26.4	30.3	71.0	14.0	26.8	31.0	71.8
2	12.9	24.6	27.9	65.4	13.6	26.2	29.7	69.5	13.9	26.5	28.7	69.1
3	14.1	25.8	29.7	69.6	14.3	25.8	30.4	70.5	14.0	25.5	29.5	69.0
4	15.9	27.7	32.2	75.8	14.1	27.2	31.0	72.3	14.4	27.1	31.0	72.5
5	13.4	25.6	28.4	67.4	13.4	25.8	29.8	69.0	13.7	25.1	29.0	67.8
6	12.8	24.0	28.5	65.3	12.7	24.3	28.0	65.0	12.8	24.8	28.7	66.3
7	14.0	27.9	30.6	72.5	14.5	25.5	28.4	68.4	14.6	25.4	28.6	68.6
8	12.7	26.0	28.3	67.0	12.9	25.7	29.2	67.8	13.2	25.6	28.7	67.5
9	15.3	30.3	35.1	80.7	15.8	29.7	34.5	80.0	15.5	29.6	36.3	81.4
10	14.8	28.0	32.1	74.9	14.9	28.1	31.9	74.9	14.9	28.2	31.3	74.4
11	13.7	27.5	31.6	72.8	14.1	27.6	31.4	73.0	13.9	27.8	31.0	72.7
Totals				783.1				781.4				781.1
Mean scores				71.19				71.03				71.01

APPENDIX D (Continued)

Group one												
Subject	Pretest				Midtest				Posttest			
	110	200	220	Total	110	200	220	Total	110	200	220	Total
12	13.3	25.4	30.3	69.0	13.2	25.1	28.9	67.2	13.0	24.1	26.4	63.5
13	12.6	24.2	27.4	64.2	12.7	23.8	26.4	63.4	12.6	23.3	25.8	61.7
14	12.5	23.1	25.1	60.7	12.5	23.0	24.9	60.4	12.3	22.4	24.6	59.3
15	13.2	24.0	27.3	64.5	13.0	23.4	26.3	62.7	12.9	23.8	25.7	62.4
16	15.4	26.5	31.3	73.2	15.0	27.9	31.3	74.2	14.3	26.6	30.3	71.2
17	12.5	23.5	27.6	63.6	12.9	23.3	25.8	62.0	12.3	23.4	25.0	60.7
18	13.0	24.8	29.6	67.4	13.3	24.4	28.1	65.8	13.1	23.9	26.7	63.7
19	13.2	25.3	29.8	68.3	13.8	25.4	29.2	68.4	13.3	25.6	27.4	66.3
20	12.5	24.0	28.1	64.6	12.7	22.9	25.6	61.2	12.3	21.9	25.2	59.4
21	13.1	24.6	28.7	66.4	13.9	25.6	28.9	68.4	13.7	25.2	27.6	66.5
Totals				661.9				653.7				634.7
Mean times in seconds				66.19				65.37				63.47

APPENDIX D (Continued)

Group two												
	Pretest				Midtest				Posttest			
Subject	110	200	220	Total	110	200	220	Total	110	200	220	Total
22	13.0	25.2	29.4	67.6	13.2	25.1	28.6	66.9	12.7	23.9	27.0	63.6
23	13.1	24.8	29.0	66.9	13.4	25.1	28.9	67.4	13.5	25.1	27.4	66.0
24	12.4	23.7	29.3	65.4	12.7	23.8	26.9	63.4	12.7	23.7	26.9	63.3
25	13.4	24.5	30.1	68.0	13.5	25.2	29.1	67.8	13.4	24.4	26.8	64.6
26	12.8	24.4	27.8	65.0	13.3	24.4	27.4	65.1	13.1	23.8	26.4	63.3
27	12.0	22.0	25.0	59.0	12.0	22.3	25.1	59.4	12.5	21.9	24.4	58.8
28	12.8	24.3	27.6	64.7	12.6	22.7	25.8	61.1	12.8	23.2	25.8	61.8
29	13.0	23.5	27.4	63.9	12.6	23.0	26.9	62.5	12.5	22.8	25.7	61.0
30	12.8	24.4	27.6	64.8	12.8	23.5	26.5	62.8	12.8	23.4	26.0	62.2
31	13.2	24.9	27.8	65.9	12.9	23.7	26.9	63.5	13.0	23.5	26.4	62.9
32	12.9	24.3	27.4	64.6	13.6	24.3	27.4	65.3	13.2	23.8	26.5	63.5
Totals				715.8				705.7				691.0
Mean times in seconds				65.07				64.11				62.82

APPENDIX E

Raw Data on the Oxygen Uptake Test

		Pretest							Posttest						
Subject	Group	Uncorrected volume	Correction factor	Corrected volume	True oxygen	Maximum VO_2 In liters	Weight in kg	ml/kg/min	Uncorrected volume	Correction factor	Corrected volume	True oxygen	Maximum VO_2 In liters	Weight in kg	ml/kg/min
1	GC	98.0	.934	91.53	.0347	3.18	79.55	39.97	103.0	.912	93.94	.0412	3.87	78.64	49.21
2	GC	73.2	.918	67.20	.0457	3.07	62.73	48.94	75.0	.916	68.70	.0499	3.43	62.73	54.68
3	GC	96.8	.917	88.77	.0379	3.36	76.37	44.00	104.4	.916	95.63	.0357	3.41	76.82	44.39
4	GC	84.6	.918	77.66	.0337	2.62	54.09	48.44	94.4	.916	86.47	.0340	2.94	54.54	53.91
5	GC	92.8	.926	86.12	.0361	3.11	75.91	40.97	97.0	.915	88.76	.0395	3.51	75.45	46.52
6	GC	76.2	.921	70.18	.0423	2.97	66.36	44.76	98.4	.913	89.84	.0399	3.58	64.55	55.46
7	GC	106.6	.920	98.07	.0352	3.45	61.82	55.84	118.6	.910	107.93	.0347	3.75	62.73	59.78
8	GC	99.2	.921	91.36	.0357	3.26	70.00	46.57	119.6	.900	107.64	.0337	3.63	69.09	52.54
9	GC	84.8	.928	78.69	.0399	3.14	81.36	38.59	No posttest						
10	GC	68.4	.918	62.79	.0364	2.29	45.91	49.90	No posttest						
11	GC	55.8	.929	51.85	.0415	2.15	51.82	41.49	No posttest						
12	G1	65.2	.917	59.79	.0473	2.83	74.55	37.96	92.8	.891	82.68	.0449	3.71	72.23	51.36
13	G1	121.0	.921	111.44	.0347	3.87	71.36	54.23	128.6	.910	117.03	.0354	4.14	72.73	56.92
14	G1	119.8	.920	110.22	.0367	4.04	62.27	64.88	135.0	.891	120.29	.0349	4.20	60.91	68.95
15	G1	116.2	.920	106.90	.0406	4.34	65.00	66.77	135.4	.917	124.16	.0362	4.49	66.36	67.66
16	G1	105.0	.933	97.97	.0397	3.89	72.73	53.49	128.6	.909	116.90	.0359	4.20	71.82	58.48
17	G1	85.6	.914	78.24	.0399	3.12	73.64	42.37	103.6	.896	92.83	.0361	3.56	75.00	47.47
18	G1	75.8	.938	71.10	.0395	2.81	59.55	47.19	105.0	.891	93.56	.0365	3.41	58.64	58.15
19	G1	63.2	.918	58.02	.0391	2.27	54.55	41.61	100.0	.891	89.10	.0352	3.14	55.91	56.16
20	G1	80.2	.914	73.30	.0371	2.72	67.73	40.16	124.2	.899	111.66	.0319	3.56	66.36	53.64
21	G1	54.0	.923	49.84	.0600	2.99	67.73	44.15	87.0	.915	79.61	.0494	3.93	69.55	56.51
22	G2	103.6	.933	96.66	.0343	3.32	70.00	47.43	109.6	.902	98.86	.0349	3.45	67.17	51.36
23	G2	57.6	.918	52.88	.0505	2.67	60.00	44.50	80.0	.900	72.00	.0443	3.19	60.91	52.37
24	G2	97.6	.924	90.18	.0382	3.45	82.73	41.70	161.2	.902	145.40	.0302	4.39	82.73	53.06
25	G2	58.4	.918	53.61	.0462	2.48	59.55	41.65	96.0	.912	87.55	.0395	3.46	61.36	56.39
26	G2	84.8	.918	77.85	.0357	2.78	52.73	52.72	116.6	.902	105.17	.0309	3.25	53.64	60.59
27	G2	71.8	.918	65.91	.0472	3.11	67.73	45.93	95.4	.891	85.00	.0448	3.81	68.18	55.88
28	G2	87.2	.933	81.36	.0433	3.52	62.73	56.11	123.4	.891	109.95	.0348	3.83	63.64	60.18
29	G2	82.6	.915	75.58	.0428	3.23	72.73	44.41	107.4	.909	97.63	.0416	4.06	73.64	55.14
30	G2	82.4	.917	75.56	.0426	3.22	56.82	56.67	105.6	.891	94.09	.0373	3.51	56.36	62.28
31	G2	103.2	.915	94.43	.0404	3.81	72.27	52.72	149.2	.891	132.94	.0312	4.15	73.17	56.72
32	G2	88.8	.919	81.61	.0397	3.24	68.64	47.20	98.6	.914	90.12	.0472	4.25	69.09	61.51

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William Kirby Stewart was born April 1, 1930, in Bradenton, Florida. In June, 1948, he was graduated from Manatee High School.

From January, 1951, until January, 1955, he served in the United States Air Force, flying thirty-three combat missions in the Korean Conflict as a radio operator on a B-29.

In June, 1957, he received the Bachelor of Science in Physical Education and in August, 1959, he received the Master's degree in Health and Physical Education at the University of Florida. From 1959 until 1966 he coached and taught school at Palmetto High. In September, 1966, he accepted the position as Athletic Director at the P. K. Yonge Laboratory School of the College of Education, University of Florida. He returned to graduate school at this time in pursuance of the degree of Doctorate of Education.

William Kirby Stewart is married to the former Constance Beverly Greer and is the father of two children, Chip and Jennifer. He is a member of Phi Kappa Phi, Phi Delta Kappa, Florida Association of Health, Physical Education and Recreation, and the Florida Athletic Coaches Association.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

Charles L. Durrance

Charles L. Durrance, Chairman
Professor of Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

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This dissertation was submitted to the Dean of the College of Education and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Education.

December, 1971

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